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Chlorinated Camphene and Parathion to Control the Cotton Boll Weevil and Cotton Aphid

HAROLD D. LODEN and HORACE O. LUND, *University of Georgia, Athens*

These experiments were undertaken to test the effectiveness of two new insecticides (chlorinated camphene and parathion) against the cotton boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glover. In addition, a third material [1] whose composition is unknown to us, was tested but proved to be too toxic to the plants for further serious consideration. In the principal experiment, plots treated with calcium arsenate and untreated check plots were used for comparison. The ability of chlorinated camphene and parathion to reduce an already high aphid infestation was tested in an additional experiment in which comparisons were made with a dust of 5 per cent DDT and 3 per cent benzene hexachloride[2] amd a mixture of calcium arsenate and 2 per cent nicotine sulfate.

Ivy *et al.* (1947) found chlorinated camphene to give very promising control of several cotton pests including the boll weevil and the cotton aphid. No publications dealing specifically with the toxicity of parathion to cotton pests have as yet appeared.

CONDITIONS OF EXPERIMENTS.—The main experiment was set up as a 6×6 latin square, each plot being 30 by 17.5 feet. Each plot was separated from its neighboring plots by drift areas of the same size. In the separate experiment on aphid control, the plots were scattered and randomized, in the same area, and separated by adequate drift areas. Each treatment was replicated four times. In both experiments, the dusts were diluted with finely ground rock phosphate and applied with rotary hand dusters.

In the main experiment the 20 per cent chlorinated camphene was applied weekly beginning on July fourth when counts revealed 22 per cent of the bolls to be punctured by weevils. It was applied at the rate of 16 pounds per acre according to two schedules. The treatment labeled "chlorinated camphene early" consisted of the first three weekly applications only, with no further dusting. The treatment labeled "chlorinated camphene regular" consisted of one application for each of the 6 weeks of treatment. Parathion was applied six times at weekly intervals as a 1 per cent dust at 16 pounds per acre, while the calcium arsenate dust was applied weekly at the rate of about 6 to 8 pounds per acre. Insect infestation counts were made in the afternoons preceding

[1] S and P Manufacturing Co., Kansas City, Mo.
[2] E. I. duPont de Nemours and Co.

Table 1.—Weekly Means—per cent bolls punctured by boll weevil.

TREATMENT (BEGUN JULY 4)		JULY 11	JULY 18	JULY 25	AUG. 1	AUG. 7	AUG. 14
Chlorinated Camphene Regular		9.2	3.0	3.7	3.2	2.5	4.7
Chlorinated Camphene Early		9.2	2.3	2.5	1.5	2.3	10.3
Parathion		12.0	8.3	9.8	7.5	6.2	10.5
Calcium arsenate		16.0	4.7	3.7	2.3	1.0	4.7
Check		25.0	9.8	11.0	11.2	5.0	19.3
Mean Difference Required for Significance	5%	6.0	5.8	7.3	5.6	2.4	5.1
	1%	8.1	7.9	10.0	7.7	3.3	6.9

Table 2.—Weekly means—Aphids per 100 leaves.

TREATMENT		JULY 11	JULY 18	JULY 25	AUG. 1[3]	AUG. 7	AUG. 14
Chlorinated Camphene Regular		16.8	223.3	586.7	4967.5	990.3	958.2
Chlorinated Camphene Early		23.0	253.5	671.2	3413.6	1682.8	1757.2
Parathion		6.7	40.3	51.3	2652.5	391.2	131.8
Calcium Arsenate		108.8	678.3	6365.7	50,000.0[1]	35,000.0[2]	35,000.0[2]
Check		59.7	357.3	1077.5	5843.3	2071.0	2116.3
Mean Difference Required for Significance	5%	49.2	157.3	1727.0	1937.0	745.5	282.2
	1%	67.1	214.5	2355.4	2641.9	1016.8	384.9

[1] Estimated number of aphids on calcium arsenate plots at 500 per leaf.
[2] Estimated number of aphids on calcium arsenate plots at 350 per leaf.
[3] All plots abnormally high in counts due to dry foliage and wind when materials were applied on previous week with resulting poor coverage.

the early morning application of the insecticides.

Consideration of the "chlorinated camphene early" series in table 1 reveals that the material, as applied, seems to continue to exert its residual effect against the boll weevil for over 3 weeks, since infestation rates did not rise significantly until the fourth week after discontinuance of the dusting in this series. It will be further noted that although the calcium arsenate and the "chlorinated camphene regular" treatments resulted in statistically identical levels of control, the chlorinated camphene effected the control more rapidly than did the calcium arsenate. Parathion at the 1 per cent concentration is evidently not an effective control for the boll weevil.

It is evident from observation of table 2 that aphid infestations in the plots treated with chlorinated camphene were significantly lower than in either the check or the calcium aresnate plots, but the parathion appears to be far superior even to chlorinated camphene as a cotton aphicide.

Adequate application of the dusts on week preceding the counts of August 1 was hindered by dry foliage and high winds. As a result of this poor coverage, the aphid counts on all plots rose abruptly. This would suggest that neither parathion nor chlorinated camphene maintains any effective residual toxicity against cotton aphids for as long as 2 weeks.

Because of relatively low pest infestation, high variability within the different treatment plots, and low yields (about 0.5 bale per acre), the significance of yield differences was minimized. The only significant differences were in favor of the "chlorinated camphene regular" treatment over the treatments with "chlorinated camphene early", the parathion and the check. No other differences were noted.

During the season, high aphid popula-

Table 3.—Cotton yields under various treatments

TREATMENT		POUNDS SEED COTTON PER ACRE
Chlorinated Camphene Regular		857.6
Chlorinated Camphene Early		740.0
Parathion		708.0
Calcium Arsenate		801.6
Check		708.0
Mean difference for significance	5%	114.4
	1%	156.0

Table 4.—Additional experiment for control of already high aphid infestation—Aphids per 100 leaves (Mean of four replicates).

TREATMENT		FIRST WEEK	SECOND WEEK
Calcium Arsenate & Nicotine 16 lbs. per acre		1985	56
Chlorinated Camphene 16 lbs. per acre		1244	35
Chlorinated Camphene 32 lbs. per acre			55
Cotton Dust #10 16 lbs. per acre		2508	24
Cotton Dust #10 32 lbs. per acre			16
Parathion 16 lbs. per acre		620	3
Parathion 32 lbs. per acre			1
Check		5275	105
Mean difference required for significance	5%	2730	42
	1%	3828	57

tions developed generally in this area, especially in fields dusted with calcium arsenate. The fields chosen for these tests had previously been dusted three times with calcium arsenate, the last application having been made just one week prior to this experiment.

These experiments were then set up to determine, first how the chlorinated camphene and parathion formulations compared in effectiveness with the DDT—benzene hexachloride dust and the calcium arsenate plus 2 per cent nicotine sulfate for aphid control and, secondly to determine the effectiveness of the chlorinated camphene and parathion in reducing already-heavy aphid infestations in plots recently dusted with calcium arsenate. All dusts were applied the first week at the rate of 16 pounds per acre. The second week three more series of plots were added and dusted with double this dosage (32 pounds per acre). Counts were made two times on the plots that were dusted twice and only once on those dusted but one time with the double dosage. Unfortunately for this experiment, aphid populations were greatly reduced shortly after these tests were begun due to frequent rains.

It would appear that dusts of calcium arsenate plus 2 per cent nicotine sulfate, DDT—benzene hexachloride dust, and chlorinated camphene are about equally effective in reducing high aphid infestations. Parathion is significantly even more effective. Increasing the dosage of chlorinated camphene, DDT—benzene hexachloride and parathion from 16 pounds to 32 pounds per acre does not significantly increase the degree of aphid control.

SUMMARY AND CONCLUSION.—Chlorinated camphene and parathion dusts were tested against the cotton boll weevil and the cotton aphid in small-plot field experiments. Chlorinated camphene appears to maintain a residual killing power for the boll weevil for over three weeks, but neither chlorinated camphene nor parathion appears to exert any significant residual killing power against cotton aphids after one week. When chlorinated camphene and parathion were applied at weekly intervals, no significant aphid populations developed. Regular weekly applications of calcium arsenate and chlorinated camphene appear to be about equal in their final effect upon the boll weevil populations but the chlorinated camphene effects the control more rapidly. Parathion in the 1 per cent concentration is not effective against the boll weevil. Chlorinated camphene, DDT-benzene hexachloride and calcium arsenate containing 2 per cent nicotine sulfate are approximately equally effective in reducing already high aphid infestations, but parathion is far superior to any of these. Yields of the plots treated weekly for 6 weeks with chlorinated camphene were statistically superior to all others except the calcium arsenate plots, but the calcium arsenate plots were not significantly superior to any others.

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Ivy, E. E., C. R. Parencia, Jr., and K. P. Ewing. 1947. A chlorinated camphene for control of cotton insects. JOUR. ECON. ENT. 40(4): 513–7.

A Rare Gregarine Parasite of the Adult Honey Bee

J. D. Hitchcock, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

Gregarines are protozoan parasites. Many species have been described from the digestive tract or body cavity of various annelids and arthropods. Most insect hosts are among the Orthoptera, Coleoptera, and Diptera. Other insect orders also are known hosts, but host lists and monographs on gregarines (Watson 1915, 1916; Kamm 1922a, 1922b) do not mention any Hymenoptera.

Bhatia & Setna (1924) described a new gregarine from the digestive tract of carpenter bees, *Xylocopa aestuans* (L), in India. This was the first gregarine to be described from a hymenopterous host. Although neither cyst nor spore stages were observed, characters of the other stages seemed sufficiently distinctive to warrant their assigning this gregarine to the genus *Leidyana* Watson (1915) and naming the new species *xylocopae*.

Morgenthaler (1926, 1929, 1933) found gregarines in the intestinal lumen of honey bees in Switzerland. Some of the same bees were infected with two other protozoa, *Nosema apis* Zander and *Malpighamoeba mellificae* Prell. Giavarini (1937) in Italy found gregarines in the ventriculus of honey bees from one colony. The protozoa causing Nosema and Amoeba diseases were absent, so the heavy mortality was attributed to the gregarine, which was provisionally assigned to the species described from the carpenter bee. Fantham, Porter, and Richardson (1941) found gregarines in the intestinal tract of hive bees in Canada. Roussy (1942) found gregarines in the intestinal tract of honey bees in France in 1933 and 1936.

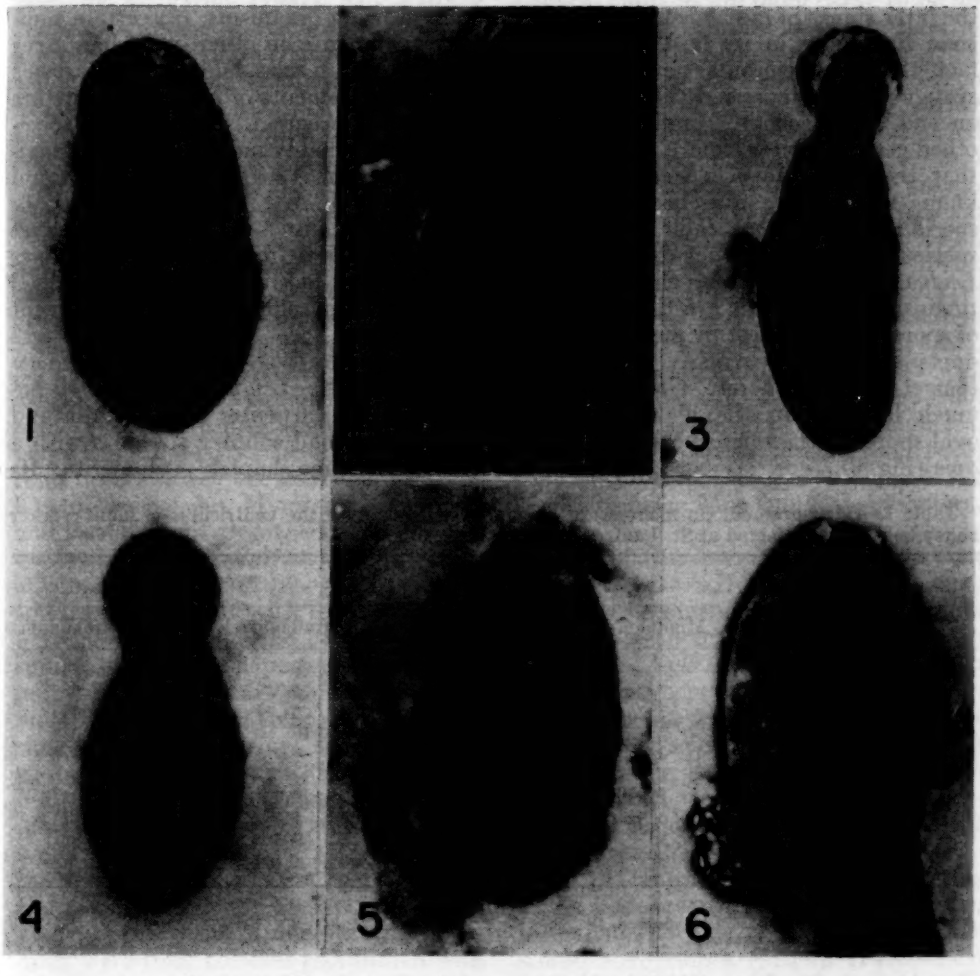
The following unpublished accounts of gregarines found in honey bees have come to the author's attention: C. E. Burnside informed me that a student at Johns Hopkins University, Baltimore, Maryland observed gregarines in honey bees about 1933. W. A. Stephen found gregarines in the intestine of a honey bee at the North Central States Bee Culture Laboratory, Madison, Wisconsin, in November 1944. C. E. Burnside and I. L. Revell found gregarines in the ventriculus of honey bees at the Intermountain States Bee Culture Laboratory, Laramie, Wyoming, in June 1947.

For many years in diagnosing diseases of the honey bee, large numbers of intestinal tracts have been examined microscopically in many laboratories throughout Europe and the United States. Consequently the scarcity of published records indicates that gregarines are rare in this host.

A Gregarine Found in Honey Bees in Minnesota.—Gregarine parasites were found in the ventriculus of 7 out of 70 living worker honey bees examined individually from five colonies at University Farm, St. Paul, Minnesota, in March and April 1935. The number of gregarines in a single bee ranged from about a dozen to several hundred. As the degree of infection increased the color of an infected ventriculus appeared to change from the normal reddish-brown to a light brown, then to a pale yellow, and finally to a dull grayish-white. The colonies seemed normal, and examinations later in the season and again the next spring failed to disclose the parasite. Three of the colonies also were infected slightly with Nosema disease. One individual bee had a double infection—gregarines and *Nosema apis* Zander. This is believed to be the first published account of the occurrence of a gregarine in honey bees in the United States.

These gregarines vary greatly in shape and size. Most of them are approximately oval, but some are almost cylindrical and others nearly spherical. A definite septum divides the body into a smaller anterior portion, called the protomerite, and a larger posterior portion called the deutomerite (Fig. 1). The protomerite varies from hemispherical to conical, and the constriction at the septum may be obvious or slight. The protoplasm has a granular appearance. A nucleus, generally spherical, occurs in the deutomerite, usually in its anterior region. The nucleus appears lighter than the cytoplasm in fresh specimens, but stains more deeply. Sometimes it is obscured by the cytoplasmic granules in both fresh and stained specimens. Staining frequently discloses a more dense, spherical, usually eccentric karyosome in the nucleus.

[1] In cooperation with the University of Wyoming.



EXPLANATION OF FIGURE 1.—Photomicrographs of gregarines, probably belonging to the genus *Leidyana* Watson (1915), from the ventriculus of adult worker honey bees found infected at St. Paul, Minnesota, in 1935.

FIG. 1.—Typical sporont showing anterior hemispherical protomerite and posterior deutomerite with nucleus and karyosome. Hematoxylin stain. ×700.

FIG. 2.—Typical cephalont showing simple rounded epimerite. Hematoxylin stain. ×800.

FIG. 3.—Cephalont with epimerite attached to loose epithelial cell of host. Hematoxylin stain. ×1000.

FIG. 4.—Small cephalont with a relatively large dense epimerite. Hematoxylin stain. ×1700.

FIG. 5.—A cephalont (small specimen at lower left) and sporont together. Hematoxylin stain. ×800.

FIG. 6.—Gregarine sporont with cluster of small oval spores (at lower left) of the microsporidian, *Nosema apis*. Nigrosin negative stain. ×450.

The protomerite of the younger specimens has an anterior rounded smooth protuberance, called the epimerite (Fig. 2), believed to be an organ of attachment. It frequently is seen attached to an epithelial cell that has broken away from the lining of the host's ventriculus (Fig. 3). There is no septum separating the epimerite from the protomerite, but the two may vary in density (Fig. 4). In the life cycle of gregarines, the stage that bears an epimerite is called a cephalont (Figs. 2 to 4). The next stage, which lacks the epimerite, is called a sporont (Figs. 1 and 6). Cephalonts are generally smaller than sporonts (Fig. 5). Subsequent stages, known as cysts and spores, were not observed, so the exact identity of this organism cannot be determined. It is possible that cyst formation and sporulation occur in the rectal contents or feces of the adult honey bee, since Keilin (1918) found

the later stages of cyst formation of *Leidyana tinei* only in its host's feces. The fact that the sporonts never occur in syzygy (two or more individuals forming an end to end chain—common in many other genera of gregarines), and the fact that the epimerite is a simple globular knob (not bearing any hooks or other specialized processes), indicate that this species probably belongs to the genus *Leidyana* Watson. Other characters distinguishing this genus are the dehiscence of spores from the cyst by means of sporoducts and the occurrence of dolioform (barrel-shaped) spores. Gregarines are much larger than the highly refractile oval spores of the microsporidian *Nosema apis* (Fig. 6).

were growing organisms, (2) certain published literature on other gregarines gives only maximum sizes, and (3) comparisons with measurements of other investigators who have measured relatively few specimens are probably more reliable for maximum figures. Living gregarines would measure somewhat larger than the data indicate, because a few of the largest specimens, judging from clear zones around them in slides negatively stained with nigrosin, show about 7 per cent shrinkage.

COMPARISON WITH GREGARINES FROM OTHER BEES.—*Leidyana xylocopae* described from carpenter bees (Bhatia and Setna 1924) had solitary sporonts with a round or dome-shaped protomerite. Its

Table 1.—Measurement (in microns) of stained gregarines from the ventriculus of adult worker honey bees found infected at St. Paul, Minnesota, in April 1935.

	CEPHALONT STAGE[1]			SPORONT STAGE[2]		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Total length	20	44	125	29	85	164
Deutomerite width	7	19	66	15	44	98
Protomerite length	7	19	37	5	17	42
Protomerite width	7	14	49	10	30	54
Epimerite length	2	11	22	—	—	—
Epimerite width	4	11	29	—	—	—
TL/LP[3]	1.5	2.3	4.6	2.6	5.0	9.5
WD/WP[4]	0.8	1.4	1.9	1.0	1.5	2.5
Nucleus diameter	5	9	17	9	17	29
Karyosome diameter	2	4	6	4	5	12

[1] 336 cephalonts examined; nuclei of 36 measured.
[2] 159 sporonts examined; nuclei of 40 measured.
[3] Total length ÷ length of protomerite.
[4] Width of deutomerite ÷ width of protomerite.

Smears were stained with eosin, nigrosin, Congo red, or Delafield's hematoxylin, the last giving the best differentiation. Minimum, mean, and maximum measurements of about 500 stained specimens are shown in Table 1. It should be noted that the term "length of protomerite" refers to the distance from the anterior to the posterior margin of the protomerite, along the longitudinal axis of the organism, and that the "length" of the protomerite is usually shorter than its "width" in the sporont stage. Also, the term "length of protomerite" in the cephalont stage, as used in this paper, indicates the distance from the anterior margin of the epimerite to the posterior margin of the protomerite, that is, it includes the epimerite. The maximum figures are probably more significant than the mean for three reasons: (1) most of the individuals presumably

cephalonts bore an epimerite in the shape of a large, simple, symmetrical sessile knob, narrowing but slightly near the base. Extremes in size of six sporonts were total length 56–174 μ, protomerite length 12–28 μ, protomerite width 12–36 μ, deutomerite width 18–51 μ, nucleus diameter 11–20 μ, TL/LP 1.5–7.0, and WD/WP 1.3–1.8. Their data and drawings are similar to those of the gregarine found by the author.

Morgenthaler (1926, 1929) did not measure or describe the gregarines he found in honey bees, but his drawing (1933) shows cephalonts having a somewhat pointed epimerite quite unlike the rounded epimerite of the specimens found by the author. Moreover, two individuals in his drawing may possibly be in syzygy, which would place his gregarine in a different genus. The gregarine described from honey

bees by Giavarini (1937) had solitary sporonts with the protomerite shaped like a rounded cupola. Its cephalonts bore an espimerite that was symmetrical, circular, unarmed, and smooth. Sixteen sporonts showed extremes as follows: total length 80–150 μ, protomerite length 13–30 μ, protomerite width 30–44 μ, deutomerite width 40–64 μ, TL/LP 4.0–7.6, and WD/WP 1.1–1.7. These measurements are well within the limits for the species described from Minnesota, and photomicrographs of both are similar. Other published reports of gregarines from honey bees (Fantham *et al.* 1941, Roussy 1942) do not include descriptions or measurements. A nigrosin-stained slide prepared by Stephen in 1944 shows gregarines from a honey bee in Wisconsin similar to those from Minnesota. Burnside and Revell found gregarines in 1 out of 20 honey bees from each of 2 colonies in Wyoming in June 1947. The author stained smears satisfactorily with Ehrlich's hematoxylin. These show the organism to be similar in size and shape to the gregarines found in Minnesota. Examination of 80 more bees from each colony failed to disclose any more gregarines, so the infection was not over 1 per cent. The same 100 bees from each colony had no Amoeba disease, but did show 38 and 59 per cent Nosema infection.

POSSIBLE RELATION OF INFECTION TO CLIMATE.—The honey bees found infected with gregarines in Minnesota and Wyoming were from colonies established with package bees received less than 3 weeks previously from the South. Since the brood cycle of the worker requires 21 days, these bees must have been reared there and probably became infected before shipment. The possibility of northern bees having drifted to these colonies is very unlikely, because the gregarines found in St. Paul were discovered the same day the package bees were installed, while those found in Laramie were in bees from an apiary where there were no overwintered colonies. The infected bee found in Wisconsin was from a greenhouse colony. A heavy mortality of honey bees believed to be due to gregarines was observed in Italy (Giavarini 1937). An apparent 100 per cent infection of carpenter bees by gregarines occurred in India (Bhatia and Setna 1924). These records may indicate that bees in tropical or subtropical climates are more likely to be infected with gregarines than are bees in more temperate regions.

GREGARINES OF THE SAME GENUS REPORTED FROM OTHER INSECTS.—Other species of *Leidyana* have been reported from other insects as follows: *L. erratica* (Crawley) (Watson 1916) from the intestinal tract of at least five species of crickets: Orthoptera; in Ill., N. J., N. Y., Ohio, Pa., and India (Watson 1915, Semans 1943). *L. gryllorum* (Cuénot) (Watson 1916) from the intestinal tract of at least five species of crickets: Orthoptera; in Ohio, France, and India (Semans 1943). *L. tinei* Keilin (1918) from the intestinal tract of the larva of a tineid moth: Lepidoptera, in England. *L. ephestiae* Daviault (1929) from the intestinal tract of the larva of the Mediterranean flour moth, Lepidoptera, in France.

POSSIBLE SOURCES OF INFECTION IN HONEY BEES.—Hypothetically, honey bees may become infected with gregarines from other insects. The Mediterranean flour moth, *Ephestia kühniella* Zell., which infests honeycombs (Essig 1940), has been found infected with gregarines (Daviault 1929). The wax moth, *Galleria mellonella* (L.), and the lesser wax moth, *Achroia grisella* (F.), commonly infest honeycombs (Paddock 1930), as does also the Indian-meal moth, *Plodia interpunctella* (Hbn.) (Dunham 1929). Certain dermestid beetles are known to harbor gregarines (Steinhaus 1946), and have been found in stored honeycombs (Milum 1940b). Several other moths and beetles occasionally infest honeycombs or nests of other bees Linsley 1942). These pests might contaminate honeycombs with their feces containing gregarine spores, which could infect honey bees.

Carpenter bees in India are known to be parasitized by gregarines (Bhatia and Setna 1924). These and other bees, such as bumble bees, might pass gregarines to honey bees by fecal contamination of drinking water, or by honey bees robbing their stores. Pests common to both bumble bee nests and honey bee combs (Milum 1940a) might serve to carry gregarines from one to the other.

It is possible that gregarines from other insects, when growing in the honey bee, would be modified morphologically, especially as to size, because of being in an unusual host. Under these conditions they

might not be recognized as the same species. It is also possible that host specificity may be very strict, so that even if gregarines from other insects should gain entrance to the honey bee, they would be unable to grow in it.

SUMMARY.—A gregarine from carpenter bees in India was the first known from Hymenoptera. Gregarines from honey bees have been reported from Switzerland, Italy, Canada, and France; unpublished records are known from Maryland, Wisconsin, and Wyoming. Descriptions, measurements, and photomicrographs are given of gregarines, probably belonging to the genus *Leidyana*, found in the ventriculus of honey bees in Minnesota. This is apparently different from the gregarine reported from honey bees in Switzerland, but similar to those from this host in other localities and to the gregarine from an Indian carpenter bee. Infection may be related to climate. Other gregarines of the same genus have been reported from various Orthoptera and Lepidoptera. There is a possibility of honey bees becoming infected from other insects.—8-25-48.

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Polyhedrosis, ("Wilt Disease") of the Alfalfa Caterpillar[1]

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Since about 1888, the alfalfa caterpillar, *Colias philodice eurytheme* Bdvl., has been known to be subject to infectious diseases of one kind or another. Only recently, however, has the etiology of the most widespread of these diseases been clarified. The malady to which we have reference is the polyhedrosis of the caterpillar and pupa of the alfalfa butterfly, and is caused by an ultramicroscopic virus. It is commonly called "wilt" or "wilt disease," and is one of a large number of such infections which occur in certain lepidopterous and hymenopterous insects. These diseases are characterized by the formation, in the nuclei of the infected tissue cells, of large numbers of microscopically visible, highly refractive inclusion bodies, called polyhedra, and usually by marked liquefaction and disintegration of internal body tissues.

Although the polyhedroses of some insects, such as those of the silkworm and the gypsy-moth caterpillar, have been reasonably well studied, the polyhedrosis of the alfalfa caterpillar has heretofore received but little attention from the investigational standpoint. It was apparently first reported in 1911 and again in 1914 by Wildermuth who considered it to be the most common natural enemy of the caterpillar in the Imperial Valley of California during 1910. Wildermuth believed the etiology of the disease to be bacterial in nature, as did Brown (1930) who ascribed its cause to *Staphylococcus flaccidifex* (Glaser & Chapman). Although they did not actually observe the disease, Chapman & Glaser (1915) suspected that the caterpillar was susceptible to a "wilt disease," or to "a disease similar to wilt." In 1935, Dean & Smith in Kansas correctly attributed the infection to a polyhedral virus. Their statement was subsequently confirmed by the actual demonstration of polyhedra in diseased larvae in California by the writer (Steinhaus 1945).

During the past several years the disease in California has been under more or less constant observation, and a considerable amount of laboratory experimentation has been conducted on the nature of the infection and its causative agent. These investigations are continuing but it will be several years before the work as it is now planned can be completed. In the meantime, it is thought desirable to make available some of the information so far accumulated, and to provide those concerned with alfalfa-caterpillar population and control studies with a preliminary report of our observations on the disease. Accordingly, the present paper is of the nature of a preliminary progress report written for the purpose of presenting some general information on the subject.

SYMPTOMS AND POST-MORTEM CHANGES.—The first discernable symptoms of polyhedrosis in the alfalfa caterpillar usually begin to appear about 4 or 5 days after infection and consist of a lessening of the animal's appetite and of its general activity and mobility. Soon thereafter the normally green color of the larva changes to a pale, yellowish, or grayish-green, sometimes giving the caterpillar a mottled appearance. Shortly before death, certain areas of the insect's integument may become darkened. By this time the animal is usually very flaccid and somewhat wrinkled in appearance, and much of the normal plumpness of the body is absent. In general, the insect dies of the disease anywhere between 5 and 10 days, usually about 7 days, after infection. During the winter months in the laboratory individuals are frequently noticed which survive 3 weeks after infection.

Soon after the caterpillar dies, the cadaver assumes a "wilted" or "melted" appearance, and breaks down into a disintegrating, decaying mass (Fig. 1, *A*). The dead insects usually remain attached to the alfalfa, frequently hanging by their prolegs (Fig. 1, *C*). In fields through which an epizootic has just passed, thousands of "wilted" larvae may be seen hanging from the plants. With the slightest disturbance the integument breaks and a thick, dark-colored fluid is liberated. Eventually the insect dries down to dark, shriveled, rather brittle remains.

Pupae may also show symptoms of the disease but the somewhat rigid pupal case usually prevents the "wilting" of the

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[2] Photographs in this paper by Kenneth M. Hughes.

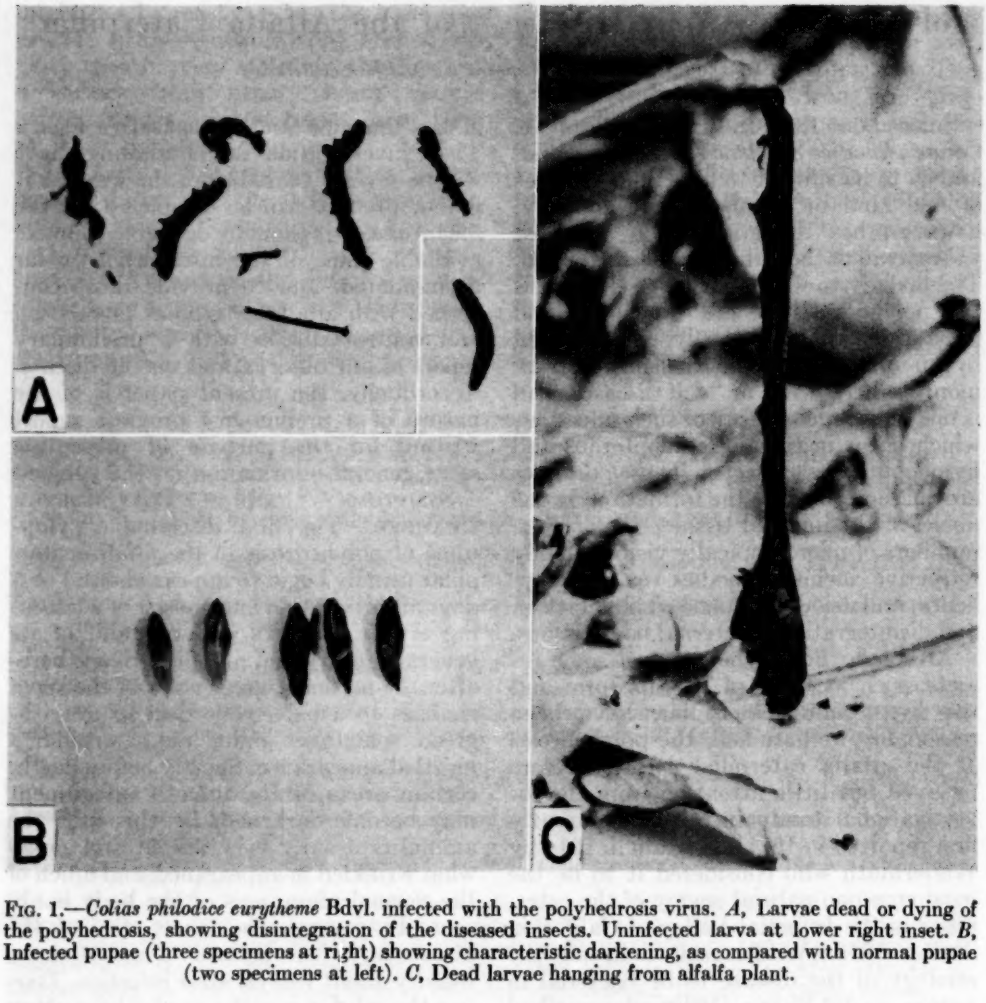

FIG. 1.—*Colias philodice eurytheme* Bdvl. infected with the polyhedrosis virus. *A*, Larvae dead or dying of the polyhedrosis, showing disintegration of the diseased insects. Uninfected larva at lower right inset. *B*, Infected pupae (three specimens at right) showing characteristic darkening, as compared with normal pupae (two specimens at left). *C*, Dead larvae hanging from alfalfa plant.

insect. Infected pupae are usually darker in color than are uninfected individuals, and at first are frequently mottled with dark and light areas (Fig. 1, *B*). Adult insects never emerge from such pupae which have become markedly darkened. Although the virus may be associated mechanically with the adults, and polyhedra may occasionally be found to have been carried over from very lightly infected larvae and pupae, the butterflies are not known to succumb to the infection. This general insusceptibility of adults to polyhedral viruses is characteristic of most polyhedroses of Lepidoptera. The eggs may be contaminated with the virus by the female butterfly but it is believed that this represents external contamination only and that the egg itself is not infected.

No species of insect other than the alfalfa caterpillar has been found to be susceptible to the virus of this lepidopteran.

GENERAL HISTOPATHOLOGY AND PATHOGENESIS.—Upon examining with a light microscope, the body contents of an alfalfa caterpillar sickened or just dead of the polyhedrosis, large numbers of highly refractive, crystal-like bodies may be seen suspended in the body fluids. These are the polyhedra which characterize this disease as one belonging to that group of infections known as polyhedroses or polyhedral diseases. The causative virus is also present in the body contents but is too small to be demonstrated with an ordinary light microscope. The polyhedra visible in such preparations originate in the nuclei of the cells of certain tissues. Their appearance in the latter location

can best be seen in histological preparations.

Longitudinal and cross-sections of a diseased caterpillar show polyhedra prominently present in the cells of the hypodermis, adipose tissue, and tracheal matrices. (Perhaps one of the earliest microscopic signs of the disease is evident in the hemocytes or blood cells of an infected larva. Smears made of the blood of a caterpillar in the earlier, as well as later, stages of the disease frequently show the nuclei of the leucocytes to contain polyhedra.) In sections treated with picric acid and then stained with iron hematoxylin, the polyhedra stain a dark purple or almost black. The nuclei of the infected cells are hypertrophied to a greater or lesser degree apparently depending upon the number of polyhedra contained within the nuclear membrane. The size of the polyhedra within any given nucleus is fairly constant although there may be considerable variation between the sizes of the polyhedra in different cells of the same tissue.

The usual size of the polyhedra varies from 1.0 to 3.0 microns in diameter. Exceptionally large polyhedra (4.0 to 5.0 microns) are seen occasionally; the significance of these forms is not clear. Ordinarily the polyhedra show 3 to 6 sides, although they vary greatly in shape. The corners are angular but somewhat rounded. The polyhedra themselves are never round or spherical. They stain feebly or with difficulty with most aniline dyes. They may be differentiated from fat droplets and from urate crystals by their shape and by the fact that unlike fat droplets they are insoluble in ether and xylol and do not stain with Sudan III, and unlike most crystals seen in insects the polyhedra are not optically active when viewed with polarized light. They are insoluble in water and alcohol, but are soluble in acids and alkalies. Since the polyhedra of the alfalfa caterpillar polyhedrosis, like those of the silkworm polyhedrosis, in all probability consists largely of nucleoprotein, it is not surprising that they stain yellow with picric acid indicating the presence of protein in their make-up. The exact relation between the polyhedra and the causative virus has not yet been determined with certainty. It is probable that it is similar to that which Bergold (1947) has shown to exist between the polyhedra and virus of the silkworm polyhedrosis, in which case the virus constitutes about 3 to 5 per cent of the content of the polyhedron. The remainder of the polyhedron is a noninfectious protein.

Histological sections prepared from larvae in advanced stages of the disease or from larvae at the time of death show the vast amount of cellular destruction which accompanies the disintegration of the insect's tissues. The size and number of polyhedra in the nucleus of the infected cell have increased to such an extent that the greatly hypertrophied nucleus occupies almost the entire space of the cell, or has burst and liberated the polyhedra into the extracellular spaces. As the cell walls are broken down, large masses of polyhedra accumulate in the space occupied by the tissue, and are also shed into the general coelomic cavity. Several stages of this process are shown in figure 2.

On the basis of the histopathological changes observable in sectioned material, and from our knowledge of other polyhedroses, a fairly clear idea can be gained of the pathogenesis of the polyhedrosis of the alfalfa caterpillar. It is generally assumed that in nature these virus-containing polyhedra (and possibly the raw virus) are ingested by the caterpillar when this material is consumed along with the animal's food. Once within the alimentary tract of the insect, it is believed that, due to the action of the digestive juices and the alkalinity of the gut, the virus is freed from the polyhedra, penetrates the gut epithelium and thus gains entrance to the body cavity. Within the body cavity the virus circulates in the blood until it contacts and penetrates the tissues (blood cells, hypodermis, fat body, tracheal matrices) that are particularly susceptible to invasion by it. The virus apparently penetrates through the cytoplasm of the cell to the nucleus where it undergoes multiplication.

In the case of the alfalfa caterpillar the development of the virus and the accompanying polyhedra in the nucleus of the host cell has not been observed in as great detail as it has in the case of the virus and polyhedra in other insects such as the silkworm, for example. It may be assumed, however, that since the two diseases are of the same general type, the processes are essentially the same. That is, after the nucleus is invaded, the chromatin material fuses into a dense, highly

chromatophilic mass within which appear minute refractive bodies. These bodies gather at the periphery of the mass and form more or less of a ring about it. According to some authorities the diseased nucleus contains a liquid which apparently results from the liquefaction of some of the chromatin material. In this liquid the polyhedra begin to appear as very small particles. As they increase in size they become more refractive, do not take stains readily, and eventually fill the entire nucleus which becomes greatly hypertrophied. Some cytoplasmic changes, such as the disintegration of the mitochondria, also probably take place.

The polyhedra-containing nucleus increases in size until it is destroyed and the entire cell disintegrates. The virus and polyhedra are thus liberated into the body cavity of the insect. As the cells disintegrate there is also an accompanying lysis of the affected tissues. After the insect dies, disintegrative changes occur in those tissues not containing polyhedra (*e.g.*, in the muscles, intestinal epithelium, Malpighian tubes, nerves).

THE CAUSATIVE VIRUS.—The virus responsible for the polyhedrosis in the alfalfa caterpillar has been shown with the electron microscope to be a rod-shaped structure approximately 40 by 300 millimicrons in size (Fig. 3, *B*). The virus particles may occur singly or in small linear bundles of several members each. A full description of the virus as well as the methods of purifying it will be presented in another paper.

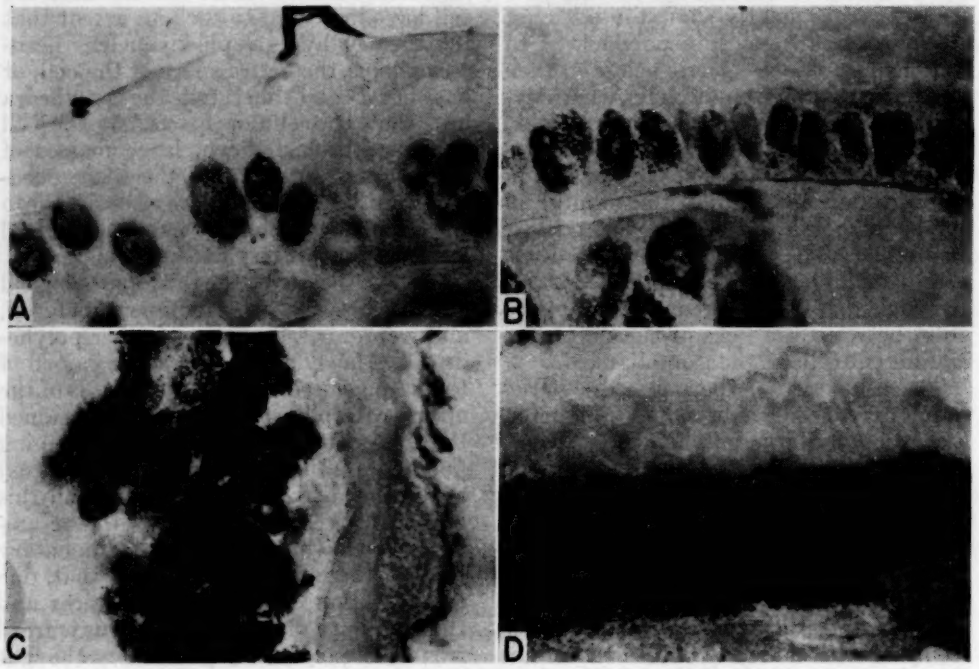

FIG. 2.—Cross sections through the hypodermis area of an alfalfa caterpillar infected with the polyhedrosis virus, showing progressive stages in the histopathology of the hypodermal cells. The dark staining bodies are the polyhedra. *A*, Hypodermis early in infection; polyhedra are forming in cell nuclei. *B*, Somewhat later stage; polyhedra have formed in almost all the nuclei which are greatly hypertrophied. *C*, Still later stage (axis of photo reversed); the hypertrophied nuclei containing polyhedra are breaking down and the cellular membranes are being ruptured, liberating the polyhedra. *D*, Very late stage; the nuclei and cells of the hypodermis have completely dehydrated.

The virus is known to be filterable through bacteriological filters of coarse to medium porosity. Most of the physical and chemical agents which destroy bacteria also destroy the virus associated with the polyhedron. It is very resistant to drying and can retain its infectivity in a dried state for at least a year (extent of tests so far completed).

Whether or not more than one strain of

virus is involved in the various epizootics which occur in different localities has not been ascertained. It is possible that strains of different virulence do exist but the identification of such is an extremely difficult undertaking since the insect host does not exhibit the wide range of symptoms which make possible such determinations with other viruses in other animals and in plants. That the virus which infects the alfalfa caterpillar is not the same one which infects certain other alfalfa insects (*e.g.*, the western yellow-striped armyworm, *Prodenia praefica* Grote), has been definitely proved.

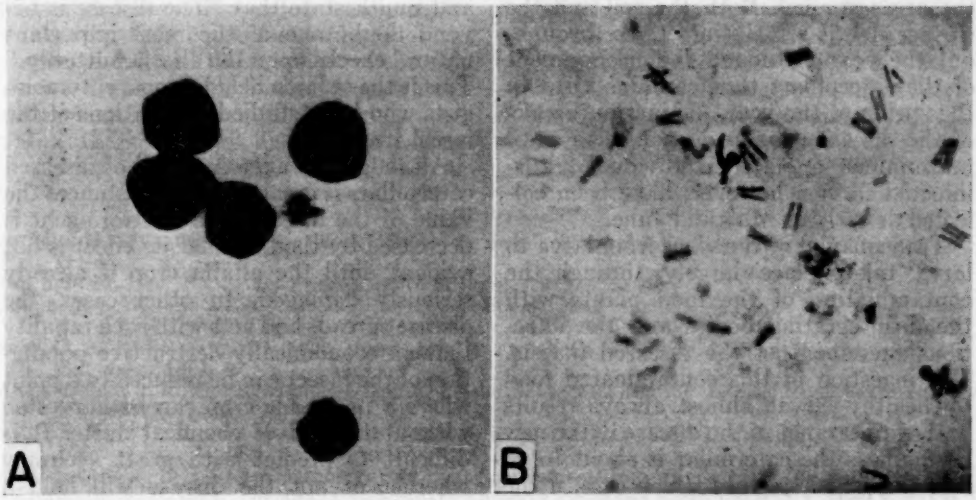

FIG. 3.—Electron micrographs of the polyhedra and the virus particles of the alfalfa caterpillar polyhedrosis. Magnification approximately 12,000×. *A*, Polyhedra. *B*, Virus particles occurring singly and in groups or characteristic bundles.

The bacterium isolated by Brown (1930) from diseased larvae collected in Kansas, and considered by him to be the causative agent of the disease, is apparently the species we have isolated with great regularity from both normal and diseased caterpillars. Michelbacher & Smith (1943) also noticed the presence of this microorganism, cultures of which are white to light yellow in color. It usually occurs in the form of a diplococcus or in short chains of up to ten members, although only rarely are there more than six members in a chain. Brown determined the strains he isolated as *Staphylococcus flaccidifex* (Glaser & Chapman), a species of questionable validity. A rather thorough study of five strains we have isolated from California caterpillars indicates that the bacterium is in reality identical with or closely related to *Streptococcus faecalis* Andrewes & Horder, a rather common enterococcus. That the insect acquires the coccus along with its food is suggested by the fact that it is frequently absent in first and second-instar larvae, and that it can be isolated from the leaves of alfalfa which have not previously been in contact with the insect or its droppings. The bacterium is definitely not the exciting cause of the disease; this property may be ascribed entirely to the virus. Its secondary role, if any, has not been determined.

EPIZOOTIOLOGY OF THE DISEASE.—In nature, the polyhedrosis of the alfalfa caterpillar may be rather explosive and extensive in character or it may be rather subdued and localized. The disease probably occurs throughout the alfalfa-growing regions of the United States and wherever else the insect has established itself.

The nature and extent of any particular epizootic appears to be determined, to a large extent, by certain environmental conditions and predisposing causes. The most important of these factors are probably concerned with temperature and humidity relationships. Apparently, both relatively high temperatures and high humidities may tend to favor the disease, but at times the correlation between these

factors and the extent or incidence of the disease seems obscure. Sometimes the simple expedient of irrigating appears to facilitate an outbreak of the infection in the field concerned. Epizootics are most noticeable at times of high host densities. However, the exact relation between outbreaks of the disease and high host populations remains to be determined.

Tests made of the top soil, stubble, and surface debris from alfalfa fields show the virus to be present in these materials throughout the alfalfa-growing districts of the areas studied. Both the soil and the surface debris remain infectious throughout the year. Although the environment of the caterpillars thus contains virus in the spring of the year, distinct outbreaks of the disease usually do not occur until midsummer or later. Individual virus-infected larvae, however, have been collected as early as May and June.

Transmission of the virus from larva to larva takes place largely through the contamination of the food plants with the disintegrating bodies and the infectious excrement of the diseased insects. The ingestion of this contaminated food by healthy larvae almost always results in the appearance of the disease in the new host unless the caterpillar is about to go into the pupal stage in which case, if the pupa itself does not succumb, the insect may survive to the adult stage. Transmission of the virus by way of the egg may occur, but in such cases the virus apparently does not pass through the interior of the egg but is associated with a virus from the surrounding environment or with the exterior. This is indicated by the fact that eggs which have been sterilized for 90 minutes in 10 per cent formaldehyde yield disease-free larvae. The wind may aid in the dissemination of the virus by the distribution of dust particles containing the virus itself or the polyhedra which harbor the virus. That the virus is airborne in the strict sense of the word does not appear likely on the basis of laboratory observations. The probable role of parasitic insects, such as *Apanteles medicaginis* Mues., in the transmission of the virus is being investigated.

A great deal of investigation still needs to be done on the epizootiology of this disease. We know very little concerning the nature of the epizootic wave in this disease and even less about the interepizootic periods. It is the type of information most needed if we are to have a basic understanding of the virus diseases of insects from the standpoint of their ecology and their use in the control of insect pests.

ECONOMIC IMPORTANCE.—Since alfalfa is one of the most important crops in certain large areas of the United States, it is obvious that any factor which may act to prevent damage to the plant is of considerable economic importance. The polyhedrosis of the alfalfa caterpillar is certainly one of these factors. Michelbacher and Smith state that "The disease is beyond doubt one of the most important natural checks upon the alfalfa butterfly." This is the opinion held by most entomologists who have studied populations of the insect in nature.

Although the aggregate toll of diseased caterpillars is great, in many instances the value of the disease as a control agent is decreased by the fact that its effect is not evident until the alfalfa crop is already seriously damaged. In other cases, the disease spreads and acts with such rapidity that an economically destructive population of the insect can be reduced to a point where a profitable crop can be harvested without the aid of chemical dusts. It is difficult to predict with great accuracy whether or not the disease will hold a population below an economic level. As indicated by Smith (1948), populations containing over 15 per cent of larvae with symptoms of the disease may need no chemical treatment, but caution should be used in making any prediction to this effect unless the incidence of the disease increases to a considerably higher percentage.

As pointed out by Michelbacher and Smith, in fields where the *Apanteles* parasite is unable to hold the caterpillars in check, the virus becomes the most important natural factor in controlling the alfalfa-caterpillar population. When the disease occurs in epizootic proportions it is possible that many of the *Apanteles*, which parasitizes the first three instars of the caterpillar, are destroyed along with their hosts. On the other hand, in epizootics of moderate intensity, the majority of the caterpillars killed by the disease are in the last two instars. The insect parasites may kill the smaller larvae while the virus operates against the larger larvae. Thus, the virus may indirectly be re-

sponsible for a higher population of *Apanteles* in adjacent fields than would otherwise be present.

A few attempts have so far been made to distribute the virus artificially over a small area for the purpose of reducing populations of the caterpillars to below an economic level. In general these attempts have been successful. Experimental plots (portions of larger fields) having low to moderate numbers of caterpillars present were sprayed with aqueous suspensions of infectious material. Within 7 to 10 days the populations in these plots were greatly reduced by the disease (as compared with control plots) and the few larvae remaining were infected with the virus. These attempts at instituting the biological control of the pest have also shown rather clearly that an epizootic can be initiated in a population of low density (20 to 30 larvae per 10 sweeps) and that in experimental plots even these low populations can be substantially reduced by the artificial dissemination of the virus.

CONCLUDING STATEMENT.—The alfalfa caterpillar, *Colias philodice eurytheme* Bdvl., is subject to a polyhedrosis (polyhedral virus disease) of which the present paper treats in a general manner. Investigations into the nature of the disease and its causative virus are continuing, details of which will be reported in subsequent papers. In the present paper the symptoms, post-mortem changes, histopathology, pathogenesis, the causative virus, epizootiology, and economic importance of the disease are discussed and the available information on these subjects is summarized.

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New Insecticides for Cabbage Maggot Control in Western Washington[1]

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The cabbage maggot, *Hylemya brassicae* (Bouché), is a serious pest of cabbage, broccoli, cauliflower, Brussels sprouts, radish, and many other plants belonging to the mustard family or Cruciferae. In many cases the young plants are killed by the maggot whereas the old established plants are more tolerant towards maggot injury. Observations made at Puyallup, Washington, indicate that cauliflower is more seriously injured than broccoli or cabbage. A calomel dust containing 3.39 per cent mercury in a gypsum carrier (1 part of calomel to 19 parts gypsum) has been recommended for the cabbage maggot. This treatment is costly and often ineffective.

During 1947, some of the newer insecticides were tested at Puyallup and Mount Vernon against the cabbage maggot. Observations were also made on the toxic effects of these compounds on cabbage plants.

INVESTIGATIONS AT PUYALLUP.—Preliminary investigations were made on the effectiveness of the gamma isomer of benzene hexachloride for the control of the cabbage maggot. The treatments comprised application rates of 1 and 2

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pounds of gamma per acre in randomized plots with eight plants in each plot. Randomized untreated plots were maintained as controls and for data on relative intensity of maggot damage to cauliflower, cabbage, and broccoli. The cabbage and cauliflower plantings were replicated six times, but only four replications were made in the broccoli plantings.

The plants were started in the greenhouse and transplanted in the field on April 14. Cabbage and cauliflower were planted 18 inches apart in 3-foot rows, whereas broccoli was spaced 2 feet apart in the row. The gamma isomer of benzene hexachloride[4] was applied as a water suspension to the plants 4 to 6 hours after transplanting and the concentration of the material was mainly in an area of about 0.5 square foot. By applying the toxicant around the plants instead of over the entire area, the concentration was probably from 9 to 12 times in excess of the 1 and 2 pound treatments.

In the case of the cauliflower and cabbage plants, there was no indication of injury with 1 pound of gamma isomer of benzene hexachloride per acre, but at 2 pounds some stunting was observed. Broccoli responded somewhat differently in that some stems became brittle and in a few cases the wind broke them. Some roots had a warty appearance. The underground parts of the broccoli plants in the plots treated with benzene hexachloride were darker in color than in the untreated check. Root development of the plants was superior in the benzene hexachloride plots when compared with the roots on the plants in the untreated check.

There were 91.66 per cent of the 48 cauliflower plants in the untreated check killed by maggots before they developed heads. Only four, or 12.5 per cent, broccoli plants died in the untreated check plots. There were 16.6 per cent of the cabbage plants killed in the untreated plots. In some cases, wireworms were found around the stems of the dead plants. Cauliflower was apparently more easily injured or killed by the maggot than were cabbage and broccoli plantings.

From the preliminary tests there were definite indications that benzene hexachloride did reduce the maggot damage. The number of cauliflower plants that died or were killed in the plots of the different treatments was 91.66 per cent in the untreated check, 27.1 per cent in the 1 pound gamma per acre, and 16.6 per cent in the 2 pounds gamma per acre.

Broccoli of the Italian green sprouting type was used in the field investigation in which four treatments were compared with the untreated check. The treatments were 0.5 per cent gamma isomer of benzene hexachloride dust, 5 per cent chlordan dust, 5 per cent chlorinated camphene dust, calomel-gypsum dust, and the untreated checks. There were eight replications of each treatment.

Broccoli seed was planted in the seed bed in April and transplanted to the plots on June 6, 1947. The plants were spaced approximately 2 feet in the rows, 3.5 feet apart. The first application of insecticides was not made until June 17 which was too late after transplanting for optimum results. One applications of calomel-gypsum was made by banding the mixture around the stem at the rate of approximately one teaspoonful per plant. The three other insecticides were dusted on the rows with a rotary type duster. An extra quick turn of the duster handle was made so that a heavier amount of dust was concentrated around the base of each plant. The three dusts were applied again on July 14. The amounts and kinds of insecticides used calculated on an acre basis are given in table 1.

Records of infestation of the cabbage maggot on the broccoli plants were obtained by pulling all plants in each replicate for all treatments and and checking for pupal or larval forms in the soil or among the roots. If one larva or pupa was found, the plant was classed as infested. Infestation records were taken at two different periods after transplanting; four replicates were checked each time. The first set of records was obtained between August 8 and 11 and the second set of records on September 30 and October 1. The first data on maggot infestation was taken just prior to the first picking of broccoli and the last record was taken at the end of commercial production in the plots. Results on the effectiveness of the different insecticides are given in table 1 with the degree of maggot infestation at 2 and 4 months after transplanting.

Referring to table 1, it can be seen that

[4] Supplied by E. I. duPont deNemours and Co., Wilmington, Delaware. Lexone 50, 6 per cent gamma isomer of benzene hexachloride.

calomel-gypsum treatment was fairly effective two months after transplanting when compared with untreated check, but at the end of the season gave very little control. Benzene hexachloride and chlordan gave promising results as is evident by the low percentage of infestation at both periods of examination. Chlorinated camphene was ineffective. Although the maggot infestation in the benzene hexachloride and chlordan plots was approximately 20 and 25 per cent respectively, no injury to the underground parts of the plants was evident. In many cases, only one larva or pupa was found per plant in these plots, whereas in the plots treated with the calomel-gypsum and in the untreated check there were many plants infested with 10 to 25 maggots. Injury to the underground portion of the plants was severe.

Table 1.—Control of cabbage maggot on broccoli. Puyallup, Washington—1947.

Material Used (Dusts)	Amount of Material Used in Pounds per Acre	Plants and Maggot Infestation[3]			
		2 Mos. After Transplanting		4 Mos. After Transplanting	
		Number	Per Cent	Number	Per Cent
Benzene hexachloride 0.5% gamma isomer	165[1]	110	18.2	107	16.8
Chlordan—5%	130[1]	110	26.4	107	26.2
Chlorinated camphene 5%	223[1]	107	54.2	109	75.2
Calomel 3.39% mercury	85[2]	111	37.8	112	93.8
Untreated Check	—	110	88.2	104	99.0

[1] Dust applied June 17 and July 14.
[2] Calomel-gypsum applied June 17 as recommended.
[3] Infestation percentages on basis of total in four replicates.

INVESTIGATIONS AT MOUNT VERNON.—The tests at Mount Vernon were conducted in plant beds, in a field of transplanted cabbage, and later in the greenhouse to further check the injury observed in the field plots. The plant beds were 5 feet by 20 feet, in blocks of 12, and replicated four times. Five rows of cabbage, 1 foot apart, were planted in each plot, with a 2-foot space between the plots. The materials used are listed in table 2.

Plots 1, 2, 3, and 4 were treated with benzene hexachloride previous to planting, the material being worked into the soil with a garden rake. Plot 10 was treated similarly, using DDT. The remaining plots were dusted about 3 weeks after planting, with a small hand duster.

Results were obtained by removing 20 plants from each plot and recording the number of maggots in each plant. This method gave rather erratic figures, since at the time of examination, many of the maggots had left the plant to pupate, and in other plots, especially those in which treatments were made previous to planting, a great many maggots were found which evidently did not develop. Benzene hexachloride was definitely not repellent to the adult flies, since plots with the heaviest dosages had as many, if not more, eggs than the check plots. At a later date 50 plants were removed from each plot and examined for maggot injury. These were separated into three groups: (1) those badly injured, (2) those with slight injury, but not serious enough to be considered commercial damage, and (3) those with no evidence of maggot injury. The results given in table 2 combine the last two groups and gives the percentage of plants without commercial injury.

In table 2, the failure of the materials dusted on after the plants were up was probably due to the fact that the flies had already started to lay eggs before the dusts were applied.

FIELD TESTS.—The cabbage maggot also caused serious damage to transplanted cabbage plants especially varieties that were planted early. In an effort to find a practical means of control, a series of tests were arranged in commercial fields, using the owner's equipment.

Dusts containing benzene hexachloride, chlordan and chlorinated camphene, were applied by means of a fertilizer attachment on the transplanter and with a bellows-type hand duster attached in such a manner that it could be operated by the mechanism of the machine. This

Table 2.—Effectiveness of insecticides on the cabbage maggots in plant beds. Mount Vernon, Washington—1947.

Plot No.	Material	Rate per Acre	Ave. No. Maggots per Plant	Ave. No. Plants Without Commercial Injury
1	Benzene Hexachloride in soil	1 lb. gamma isomer	0.7	72.5
2	Same	2 lbs. gamma isomer	0.33	98.5
3	Same	4 lbs. gamma isomer	0.05	99.5
4	Same	8 lbs. gamma isomer	0.21	99.25
5	Benzene Hexachloride dusted on plants	0.5 lb. gamma isomer	2.7	19.5
6	Same	1 lb. gamma isomer	2.7	45.5
7	Chlordan 5%—dusted on plants	100 lbs.	4.05	20.0
8	Chlorinated camphene dusted on plants	100 lbs.	3.6	8.0
9	Calomel-gypsum 5% dusted on plants	100 lbs.	3.2	18.0
10	DDT 10%—in soil	160 lbs.	3.2	22.0
11	DDT 10%—dusted on plants	100 lbs.	2.6	12.0
12	Check—No Treatment	—	4.7	8.5

duster delivered puffs of dust at the same intervals that the plants were set, but due to mechanical difficulties, plants that received dust exactly where it was needed were rare. The fertilizer drill placed the dust on each side of the row, but too far away to be effective. Benzene hexachloride,[5] 10 per cent gamma, in a water miscible liquid was also used by adding it at the rate of 1 quart to 50 gallons of water in the starter solution. This would give approximately the same amount of toxicant per acre as the dusts. Corrosive sublimate at 5 ounces to 50 gallons was also used in this manner.

The relative effectiveness of the various materials was determined later by counting 400 plants in each plot, at the same time noting the number injured by maggots, which was evident by the reddish leaves and retarded growth. These data are given in table 3.

The percentages shown for checks were from counts made on 400 plants in the buffer rows separating the plots.

The failure of the dusts in this test is probably due to the method of application since neither the duster nor the fertilizer drill delivered the dust at the proper place.

Other tests using the liquid benzene hexachloride and also liquids containing chlordan and chlorinated camphene were conducted in three other fields, but unfortunately no maggots were found even in the check rows, so no information was gained on their effectiveness. In the first tests none of the materials caused injury to the plants, but in all of the other tests, the benzene hexachloride liquid caused very severe injury, necessitating replanting in some cases. This injury was at first

[5] Furnished by Pennsylvania Salt Manufacturing Co., Tacoma, Wash.

Table 3.—Effect of method of insecticide application on cabbage maggot control, Mount Vernon Washington—1947.

	Material	Method of Application	Per Cent Injured Plants	
			Treated Plots	Check Plots
1	Benzene hexachloride 1% gamma	by duster attachment	32.7[1]	43.0
2	Chlorinated camphene 5%	by duster attachment	27.6	31.7
3	Chlordan 5%	by duster attachment	16.5	16.7
4	Benzene hexachloride 1% gamma	by fertilizer drill	12.0	13.5
5	Chlordan 5%	by fertilizer drill	11.0	11.2
6	Chlorinated camphene 5%	by fertilizer drill	11.7	15.2
7	Corrosive sublimate 5 oz.–50 gal.	in starter solution	8.5	15.2
8	Benzene hexachloride liquid 10%–1 qt. 50 gal.	in starter solution	0.25	12.2
9	Chlordan 5%	by fertilizer drill	15.0	10.7

[1] Percentages based on data from 400 plants.

suspected to be due to the solvent (xylene), and thought to be aggravated by the presence of phosphoric acid which was used in the starter solution.

Further tests were made in the greenhouse using two brands of benzene hexachloride water miscible liquid, one containing only the gamma isomer[6] and the other a wettable benzene hexachloride powder formulated from the technical material. Water miscible formulations of chlordan and chlorinated camphene were also used. The results were: All forms of benzene hexachloride are apt to cause injury to cabbage plants when applied directly to the roots. The pure gamma isomer caused less damage than the form containing all the isomers, and the damage was more severe where phosphoric acid was used. Chlordan and chlorinated camphene did not cause damage in any of the tests, either in the greenhouse or outdoors.

SUMMARY.—Tests were conducted at Puyallup and Mount Vernon for the control of the cabbage maggot, *Hylemya brassicae* (Bouché), by using new insecticides applied by different methods and in various physical and chemical forms.

In the untreated checks, cabbage maggots killed 91.6 per cent of the cauliflower plants, 16.6 per cent of the cabbage plants, and 12.5 per cent of the broccoli plants.

Percentages of maggot infestation of different treatments at two and four month periods after transplanting were: 0.5 gamma of benzene hexachloride, 18.2 and 16.8; chlordan, 26.4 and 26.2; chlorinated camphene, 54.2 and 75.2; and calomel-gypsum, 37.8 and 93.8; and untreated check, 88.2 and 99.0 respectively.

Benzene hexachloride mixed with the soil at the rate of 1, 2, 4, and 8 pounds of gamma isomer per acre in the seed bed gave 72.5, 98.5, 99.5, and 99.25 per cent control of maggots, respectively. Two pounds per acre gave good commercial control, but was not a repellent to adult flies as many eggs were deposited. DDT mixed with the soil gave poor control. Chlordan, benzene hexachloride, chlorinated camphene, DDT, and calomel-gypsum dusted at a delayed date on the plants, 3 weeks after the plants were up, gave poor maggot control.

Dusts containing benzene hexachloride, chlordan and chlorinated camphene, when applied by a fertilizer or duster attachment on the transplanter, gave practically no control.

Greenhouse tolerance tests with cabbage plants indicated that various degrees of plant injury occurred when all types and brands of benzene hexachloride tested were applied in contact with the roots. Plant injury was apparently aggravated by the addition of phosphoric acid.

Chlordan and chlorinated camphene caused no plant injury in any of the tests.—8-17-48.

[6] Furnished by California Spray Chemical Corporation, Portland, Oregon, 25 per cent gamma.

Residual Insecticides for the Control of Spider Beetles in Cereal Warehouses[1]

B. N. SMALLMAN[2]

At country points in Western Canada, milling companies own or lease warehouses for the storage and sale of flour and other cereal products. The warehouses are maintained by retail merchants or elevator agents and are usually separate unheated buildings. Mills customarily ship carlots of flour to country points so that, other conditions permitting, large stocks are maintained in the warehouses. Low winter temperatures in the unheated warehouses would be expected to deter insect infestation, and this is generally so, with one notable exception. Ptinid beetles, often called "spider beetles," are commonly present in the warehouses and survive the winter to cause serious infestation of cereal products during the spring and summer. At the request of the milling industry an investigation was undertaken to determine the

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protection afforded to warehouse stocks by certain residual insecticides.

Gray (1943) was the first to publish an account of the biology of spider beetles in prairie warehouses and to develop a method of control. *Ptinus villiger* Reit., is the species most commonly found but *P. fur L.* and *P. raptor* Sturm. also occur. The economic importance of spider beetles in cereal warehouses is due to their habit of laying eggs *through* the mesh of cotton flour sacks. Therefore, the object of any satisfactory control measure must be to eliminate the adult insects before they can reach the sacks and lay their eggs. In Manitoba, the egg-laying period extends from early May to the middle of July, and may be assumed to begin during April in the milder climate of Alberta (Smallman & Gray, 1948). There is an emergence of adults in the late summer but no eggs are laid until the following spring. Accordingly, it is only during the four-month period, April to July, that warehouse stocks require protection against infestation by spider beetles.

To be effective, control measures must be continuously operative during the oviposition period; and to be practical, they must be largely independent of the attention of the individual warehouseman. These requirements are most likely to be met by the residual insecticides. A deposit of an effective residual on the floor and walls of a warehouse would be expected to prevent the beetles from reaching the stock. Alternatively, an effective residual deposit on the cereal sacks might prevent the beetles from laying eggs in the sacks. Both these possibilities were investigated.

The experiment was designed to yield information on the relative effectiveness of treating warehouses with a single or double application of six types of residual insecticides. Information was also obtained on the protection afforded by treating cotton sacks with two types of residual insecticides, and by untreated paper sacks.

METHODS.—Seventy-five warehouses were chosen for the experiment. The warehouses were scattered throughout the populated area of Manitoba, and the criterion for inclusion in the experiment was a previous record of infestation. By means of a table of random numbers, 6 groups of 10 warehouses were selected and each group was designated for treatment with one of the six insecticides; the remaining 15 warehouses were assigned to the control group and received no treatment.

The warehouse treatments were applied during April. In June, 5 of the 10 sheds under each treatment were randomly selected and re-treated. Details of the insecticides used and the dosages applied are shown in table 1.

Table 1.—Average dosage of insecticide applied per 1000 square feet.

INSECTICIDE	VOLUME OF TOTAL INSECTICIDE (LITRES)	WEIGHT OF TOXICANT (GMS.)
DDT-oil solution, 5% w:v	4.1	204
DDT-water suspension, 5% w:v	4.7	238
Gamma benzene hexachloride-oil solution, 0.5% w:v	4.0	20
Benzene hexachloride smoke pellets, 3% gamma benzene hexachloride	—	17
Magnesium oxide, mean particle size 0.5 μ	3.7	46
Aluminum oxide, mean particle size 1 μ	3.6	59

The liquid insecticides were applied to the floor and to the lower 5 feet of the walls with a knapsack pressure sprayer regulated to give a coarse spray. The magnesium and aluminum oxide were applied as dusts with a garden dust gun. The smoke pellets containing gamma benzene hexachloride were placed on small squares of tin and ignited; no precautions were taken to contain the smoke other than closing ventilators and doors. The dust and smoke treatments created a cloud of insecticide which settled on the floor and the dosages were calculated on the basis of floor areas. Shed floors were swept before any of the treatments were applied.

The dosage required for each shed was previously calculated on the basis of 200 mg. of DDT, and 20 mg. of gamma benzene hexachloride per square foot of surface; experience with the dusts indicated that about 3.5 liters per 1000 square feet of floor area gave adequate coverage. To ensure that approximately the required dosage was applied with reasonable uniformity, the amount of insecticide dispensed was determined peri-

odically during application by weighing the spray tank or by measuring the volume of dust used.

The results of the warehouse treatments were assessed by counting the spider beetle eggs or larvae recovered from three 7-pound sacks of patent flour placed in each shed. These ordinary white cotton sacks of flour were placed in the corners and under the flour racks at three widely-separated locations in each shed at the time of treatment in April and were exposed until November. The flour in the indicator sacks was sifted over an 80-mesh wire screen during June, August and November. At each sifting except the last, all insect forms were removed and the flour was returned to the sacks for a further period of exposure.

For the second part of the investigation, cotton flour sacks were treated by immersing them in a solution of technical grade DDT or dichlorodiphenyldichloroethane in carbon tetrachloride. The deposit of insecticide was determined by weighing the dry sacks on an analytical balance before and after treatment, and sacks that closely approximated a deposit of 120 mg. per square foot were selected. All sacks were previously washed in carbon tetrachloride, and check sacks immersed in the pure solvent and dried showed no increase in weight. Seven-pound paper sacks of flour with a gummed closure were also included in this section of the investigation. All sacks were filled with patent flour. One paper sack, one sack impregnated with DDT, and one sack impregnated with dichlorodiphenyldichloroethane, were exposed in each of the 15 untreated control sheds. Three untreated cotton sacks of flour were also placed in each of these 15 sheds. The sacks were exposed in the sheds from April to November and the results assessed by the method previously described.

RESULTS.—All spider beetles recovered from the indicator sacks were in the egg or larval stage. Eggs and larvae were recovered in all untreated sheds and in many of the treated sheds, at both the June and August examinations. The November examination yielded only 5 larvae and these may well have been carried over from August because of incomplete cleaning of the sacks.

Warehouse treatments.—Table 2 shows the mean number of insects recovered from warehouses under each treatment. The significance of the differences between treatments was examined by statistical analysis, and details of the analysis are given in a later section.

Table 2.—Mean numbers of insects recovered from sheds, April–November.

	One Application (5 Sheds)	Two Applications (5 Sheds)	Mean for Treatment (10 Sheds)	Reduction Over Controls Per Cent
None	—	—	186[1]	—
Benzene hexachloride smoke	124	93	108	42
Aluminum oxide	46	16	31	83
Magnesium oxide	23	35	29	84
DDT-water suspension	20	2	11	94
Benzene hexachloride-oil solution	89 (11)[2]	2	45 (7)[2]	76 (96)[2]
DDT-oil solution	2	2	2	99

[1] 15 sheds in the control group.
[2] Bracketed values result from omission of one aberrant count.

The treatments differed significantly in preventing egg-laying in the indicator sacks. With the exception of the benzene hexachloride smoke, all treatments gave significantly better protection than no treatment. Protection was best in sheds treated with benzene hexachloride-oil solution, DDT-water suspension, and DDT-oil solution; and the results obtained with these treatments did not differ significantly.

The exceptionally high count in one shed treated with benzene hexachloride-oil solution was included in the analysis, and the analysis places this treatment in about the same relation to the other treatments as when the count is omitted from the means in table 2.

Treatment with magnesium and aluminum oxide dusts gave protection intermediate between the most effective treatments and the benzene hexachloride smoke.

Crude benzene hexachloride has a strong musty odour, and this odour was characteristic of the benzene hexachloride formulations used in this investigation. Sheds treated with benzene hexachloride in oil solution were soon free of this odour, and no complaints were made by warehousemen or customers. However, sheds treated with benzene hexachloride smoke retained the odour for several weeks, and in a few cases, warehousemen and customers complained of the odour in the warehouse or in cereal products from treated sheds. Sacks of flour exposed to

benzene hexachloride smoke were submitted to two mill laboratories. Both laboratories reported a strong odour on the sacks but no appreciable odour from the flour at any stage of the baking process. Similar observations have been reported by Carpenter (1947).

Retreatment of warehouses in June failed to give significantly better protection than the single treatment in April. It should be noted that ten sheds are available for comparing the effectiveness of the different treatments, but comparisons of the effectiveness of one application versus two applications are based on five sheds.

Sack treatments.—The number of spider beetles recovered from treated sacks exposed from April to November in 15 untreated sheds was compared with the number recovered from untreated sacks in the same sheds. The mean numbers of insects per sack were as follows:

Untreated cotton sacks	62.1
DDT-treated cotton sacks	0.3
Dichlorophenyl-dichloroethane-treated cotton sacks	0.6
Untreated paper sacks	0.1

It is evident that both types of treated sacks and the paper sacks provided a high degree of protection for the enclosed flour. Untreated cotton sacks exposed in the same sheds were heavily infested.

Statistical treatment of the data.—The original data for the warehouse treatments showed a pronounced skewness of the frequency distribution and a relation between the group means and the variance. In order to carry out the analysis of variance, a transformation was required. The appropriate transformation is to logarithms (Snedecor 1946), and to accommodate zero values, unity was added to all counts before transforming to logarithms. Ten sheds were randomly selected from the 15 untreated sheds to facilitate comparisons with the groups of 10 sheds under each treatment. The analysis of variance given in table 3 shows that significant differences were found only for treatments.

DISCUSSION.—Spider beetles appear to be generally present in cereal warehouses in Manitoba, often in sufficient numbers to cause heavy infestation of cereal stocks. Thus, 45 7-pound sacks of flour exposed from April to November in 15 untreated warehouses were all infested, averaging 62 insects per sack.

The warehouse treatments were generally effective in reducing the number of insects in the indicator sacks. An effective insecticidal deposit on the warehouse surfaces would be expected to kill many of the beetles before they reach the stock and thus reduce the egg-laying potential of the original population. DDT and gamma benzene hexachloride applied to the warehouse surfaces as insecticidal sprays were apparently highly effective

Table 3.—Mean numbers of insects recovered from sheds, April-November. Transformed values, log (x+1)

	TREATMENTS						
APPLICATIONS	None	Benzene hexachloride Smoke	Alumina dust	Magnesia dust	Benzene hexachloride oil	DDT water	DDT oil
1	2.20	1.70	1.51	1.07	1.00	0.93	0.21
2	2.28	1.81	1.01	1.38	0.36	0.22	0.20
Means for treatments	2.24	1.76	1.26	1.23	0.67	0.57	0.20

ANALYSIS OF VARIANCE

Source of variation	Degrees of freedom	Mean square
Applications	1	0.68
Treatments	6	5.05*
Treatments×applications	6	0.43
Error	56	0.32

* Minimum significant difference for treatment, 0.51.

in reducing the number of adult spider beetles, and thus preventing egg-laying in the indicator sacks. Davis (1946) has reported that stored product insects may be controlled by applications of DDT to warehouse surfaces. The equal effectiveness of gamma benzene hexachloride in oil solution at one-tenth the amount of DDT applied to warehouse surfaces is in accordance with other work on the relative toxicity of these compounds (McGovran & Piquett, 1945).

Warehouse conditions and practices undoubtedly affected the results obtained with the various treatments. Thus, the loose construction of the sheds allowed large amounts of the benzene hexachloride smoke to escape and this loss may have been largely responsible for the relative ineffectiveness of the treatment. Even on a calm day the loss of smoke was apparent and was greatly increased on windy days. For this reason, the deposit of gamma benzene hexachloride from the smoke treatment was certainly less than the amount released. Another factor affecting the treatments was the number of times the shed was swept and the type of broom used. For instance, in one warehouse treated with benzene hexachloride-oil solution, a higher than average count was apparently caused by the use of a heavy, stiff-bristled broom for sweeping the shed, which probably removed much of the residue by abrasion.

Mineral dusts, such as aluminum and magnesium oxides have been reported as effective insecticides for the protection of stored seeds (Cotton & Frankenfeld, 1945; Parkin, 1944), but have not been used as residues on structural surfaces. These dusts are non-toxic and therefore offer an advantage in the control of insect pests of stored foods. Insects in contact with such mineral dusts tend to lose water at an abnormally high rate (Wigglesworth, 1945) and death results from desiccation. Applied in the warehouses, the dusts were effective in reducing the number of eggs laid in flour sacks, but not as effective as DDT or benzene hexachloride sprays. Here again, warehouse conditions undoubtedly affected the results. On windy days, a strong current of air blows through the sheds when both the shipping door and the entrance door are open. It was frequently observed that the dust was blown into the corners of the shed leaving the main floor areas free of the dust. Though warehousemen were instructed not to sweep the dust-treated sheds, and did not do so, this is not a desirable warehouse practice. It is an interesting finding that these dusts may be used as insecticidal residues on structural surfaces, but, except where warehouses are too full to permit the application of liquid insecticides, the more effective residuals are preferable.

Re-treatment of the sheds in June did not result in significantly better protection than a single treatment in April. Apparently the maximum effect of the treatments resulted from the April application, and retreatment in June had little further influence on the number of eggs laid in the sacks. Such a result might be expected with a resident population of insects in the sheds and no important outside source of infestation. Thus, a given treatment applied in April would kill a proportion of the shed population according to its effectiveness, while a second application in June would kill a similar proportion of the survivors and exert a relatively smaller effect on the egg-laying potential. However, there is some evidence that the adult beetles are not entirely resident in the sheds, and that invasion from the space under the sheds or from an occasional box car may occur. The ineffectiveness of a second application in June suggests that such outside sources of infestation did not contribute a significant number of adults during the latter part of the oviposition period or that the application in April remained effective throughout the whole period.

Cotton sacks treated with DDT or dichlorodiphenyldichloroethane, and untreated paper sacks provided a high degree of protection for the enclosed flour. The result for paper sacks is not surprising because the female beetles beetles would not be expected to be able to thrust their ovipositors through the paper. The only spider beetles recovered from paper sacks were larvae that had gained entrance by drilling holes through the paper. The protection afforded by cotton sacks treated with DDT or dichlorodiphenyldichloroethane is more difficult to explain. These compounds act slowly to kill insects, and female spider beetles would be expected to have

opportunity for egg-laying before intoxication resulted from contact with the residue on the sacks. Others (Davis, 1946; Jones, 1947) have reported that foodstuffs stored in fabric or paper sacks treated with DDT may be protected against insect invasion, presumably because the insects are killed by prolonged contact with the residue while seeking entry. Thomson (1947) suggests that surfaces treated with DDT have an irritant effect on anophelene mosquitos, preventing them from resting on treated surfaces long enough to absorb a lethal dose. Such an effect may have prevented spider beetles from remaining in contact with the treated sacks long enough to lay eggs.

In spite of their effectiveness, paper sacks are not generally acceptable to the milling industry, and sacks impregnated with DDT or dichlorodiphenyldichloroethane cannot be utilized because of the toxic hazard involved with these compounds in direct contact with foodstuffs. However, the recent development of a residual insecticide free of toxic hazard has opened the way for exploitation of the demonstrated value of cotton sacks impregnated with an effective residue.

SUMMARY.—Ptinid beetles are the most important insect pests of cereal warehouses in Western Canada because of their habit of laying eggs through the mesh of cotton flour sacks. The degree of protection afforded to warehouse stocks by six residual insecticides was investigated in a factorial experiment involving 75 warehouses. Comparisons between insecticides were based on the number of insects recovered from three seven-pound sacks of flour exposed in each warehouse from April to November.

As compared to untreated warehouses, the number of insects recovered from treated warehouses was reduced as follows: with gamma benzene hexachloride by 76 per cent or 96 per cent with DDT in water suspension by 94 per cent and with DDT in oil solution by 99 per cent. While these treatments were all very effective, they were not significantly different. Aluminum oxide and magnesium oxide applied as dusts reduced the number of insects by 83 per cent and 84 per cent respectively in comparison with untreated warehouses. No significant protection resulted from the application of gamma benzene hexachloride as a smoke. Re-treament of warehouses in June did not result in significantly better protection than the single treatment in April.

Cotton sacks impregnated with DDT or with dichlorodiphenyldichloroethane, and untreated paper sacks, gave essentially complete protection to the enclosed flour.

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Acaricidal Properties of Organic Compounds Related to DDT[1]

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The unprecedented increases observed in phytophagous mite populations on plants treated with certain of the new, highly specific, organic insecticides have resulted in acute problems of control of these pests in many areas. Such phenomena have been recorded for the following mites on apples after the application of DDT: the European red mite, *Paratetranychus pilosus* (C. & F.) (Steiner *et al.* 1944); the apple mite, *Tetranychus schoeni* McG. (Hough 1946); the Pacific mite, *T. pacificus* McG. (Newcomer & Dean 1946); and the clover mite, *Bryobia praetiosa* Koch (Carman & Fleschner 1945). They have also been reported for the citrus red mite, *P. citri* (McG.), on citrus after DDT (DeBach 1947); for unspecified mites on cotton after DDT, chlorinated camphene, and benzene hexachloride (Anonymous 1948); for the two-spotted mite, *T. bimaculatus* Harvey, and *P. pilosus* on walnuts after DDT (Ortega 1948); and for *P. citri* on citrus after chlordan and benzene hexachloride.[4]

Thus it would seem to be abundantly established that most, if not all, of the newer chlorinated hydrocarbon insecticides are valueless in controlling various tetranychid mites, and that their use may result in a pronounced increase in these mite populations, probably due to the effect of the toxicant on the natural insecticide-susceptible predators of the mites (DeBach 1947).

Therefore, it seemed of practical importance to inquire into the reasons for the ineffectiveness of such powerful insect toxicants on the tetranychid mites, in the hope of developing materials to control these pests. The interest in such a project was heightened by the recent development of two materials which have powerful acaricidal action and yet are related structurally to DDT. These materials are bis-(*p*-chlorophenoxy)-methane[5] and 1,1-bis-(*p*-chlorophenyl)-ethanol or di-(*p*-chlorophenyl)-methyl carbinol.[6] As a preliminary inquiry into the structural requirements for acaricidal action, a considerable number of compounds related to DDT or these two compounds or to both were obtained by synthesis or from commercial sources and were tested for acaricidal activity against the citrus red mite, *Paratetranychus citri*, and for insecticidal activity against the greenhouse thrips. *Heliothrips haemorrhoidalis* (Bouché). A few supplementary tests were made with the two-spotted spider mite, *Tetranychus bimaculatus*.

METHODS.—The compounds, all of which were purified by several recrystallizations from appropriate solvents, were used at 1 per cent or, where the supply of the compound was limited, at 0.1 per cent and made up as standard weight-volume solutions in acetone. Mature Valencia oranges were dipped in these solutions for 1 second and allowed to dry. Each orange was then placed in a jelly glass. Eight oranges were used for each material. Four of these fruits were infested with the citrus red mite and the remaining four with the greenhouse thrips, approximately 25 adult mites or thrips being placed on each orange. The glasses containing the mite-infested fruits were partially filled with water, and those containing the thrips-infested fruits were covered with fine-mesh bolting cloth to prevent escape of the thrips. Mortality counts were taken in 24 hours and were repeated in 48 hours where large numbers of moribund individuals were observed. If an appreciable kill was obtained at the initial concentration, the dosage was halved and the test repeated, and in most cases each dosage was replicated once. Dosage mortality curves were plotted on probit-logarithmic paper for the active compounds, and values for approximate median lethal concentrations were determined from these curves, as shown in the tables that follow.

DISCUSSION OF RESULTS.—The data in table 1, which show the comparative response of the greenhouse thrips and the

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[3] The writer wishes to acknowledge the very able laboratory assistance of R. B. Carlson and U. E. Murphy, and to thank F. A. Gunther of this station and P. Müller of J. R. Geigy, A. G., for supplying certain of the compounds used in this study.

[4] Carman, G. E. 1947. Unpublished observations.

[5] *Neotran*, the Dow Chemical Company.

[6] *DMC*, Sherwin-Williams Co.

Table 1.—Comparative toxicity of certain organic insecticides to the greenhouse thrips, *Heliothrips haemorrhoidalis*, and the citrus red mite, *Paratetranychus citri*.

Compound	24-Hour Median Lethal Concentration, Per Cent	
	H. haemorrhoidalis	*P. citri*
2,2-bis-(*p*-chlorophenyl)-1,1,1-trichloroethane (DDT), m.p. 108°–109° C.	0.001	(Nontoxic at 10.0)
Chlorinated camphene, $C_{10}H_{10}Cl_8$[1] tech. m.p. 65°–90° C.	0.0025	(Nontoxic at 1.0)
Gamma-1,2,3,4,5,6-hexachlorocyclohexane m.p. 112° C.	0.0001	1.0
1,2,4,5,6,7,8,8-octachloro-4,7-methano-3a,4,7,7a-tetrahydroindane (chlordan), b.p. 175° C./2 mm. Hg.	0.0035	1.0
Tetraethylpyrophosphate dist. 98.5%	0.0003	0.0005
0,0-diethyl-0-*p*-nitrophenyl-thiophosphate (parathion), 95% tech.	0.0001	0.0001

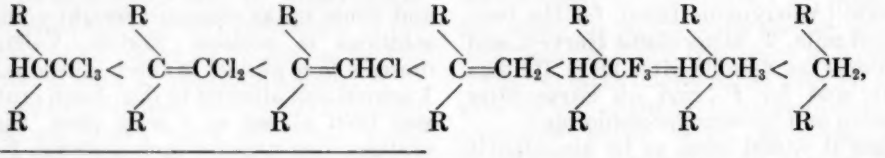
[1] *Toxaphene*, Hercules Powder Co.

citrus red mite to some common organic insecticides, amply support the original contention regarding the ineffectiveness of the chlorinated hydrocarbon insecticides against tetranychid mites. It will be noted that the chlorinated hydrocarbons DDT, chlorinated camphene, gamma-hexachlorocyclohexane, and chlordan were only about 0.2 per cent to 0.01 per cent as toxic to the mite as to the thrips. The organic phosphates, however, appeared to be about equally toxic to the two organisms, demonstrating that contact toxicants applied as residues on the fruit may be highly effective against both the mite and the thrips.

Table 2, section A, shows the results obtained with a series of DDT derivatives having various *para-para'* substituents. A number of these compounds were highly toxic to the thrips, the data being in good agreement with those of toxicity studies on other insects by other investigators (*vide* Busvine 1946, Müller 1946, Proverbs & Morrison 1947). However, none of these compounds showed any appreciable toxicity to the citrus red mite.

The effects of alterations in the aromatic ring structure of the DDT molecule are indicated in table 2, section B. The resulting compounds were nontoxic to both thrips and mite.

In table 2, section C, the effects of alterations in the aliphatic portion of the DDT molecule are presented. Here, any change from DDT resulted in a marked decrease in effectiveness against thrips, but a progressive increase in acaricidal effectiveness resulted from the successive elimination of chlorine from the trichloromethyl group. The order of effectiveness was:



where R = *p*-chlorophenyl. Of special interest was the definite acaricidal action of 2,2-bis-(*p*-chlorophenyl)-1,1,1-trifluoroethane. This compound is only weakly insecticidal, a characteristic which has been explained by Kirkwood & Phillips (1946) as being due to the fact that the trifluoromethyl group is not a lipid-solubilizing group. This has been suggested as verifying the theory of Laüger *et al.* (1944), which indicates that the di-*para*-chlorophenyl group is the toxic portion of the DDT molecule, and the trichloromethyl group the lipid-solubilizing portion. From the data reported in this paper, it appears that the trichloromethyl group is not a lipid-solubilizing agent for acaricides; this possibly indicates that either the integument or the nerve tissue of the Acarina may possess different characteristics from that of the Insecta.

It is of interest also in this connection that the substitution of fluorine for hydrogen in aliphatic compounds results in very little change in melting and boiling points and in chemical properties, as com-

Table 2.—Comparative toxicity of various DDT derivatives to the greenhouse thrips and citrus red mite.

COMPOUNDS	MELTING POINT, UNCORRECTED ° C.	24-HOUR MEDIAN LETHAL CONCENTRATION, IN PER CENT[1]	
		Greenhouse Thrips	Citrus Red Mite
A.—*Substituted diphenyltrichloroethanes*			
2,2-bis-(*p*-chlorophenyl)-1,1,1-trichloroethane	108–109	0.001	>10
2,2-bis-(*p*-fluorophenyl)-1,1,1-trichloroethane	44– 45	0.006	>1.0
2,2-bis-(*p*-bromophenyl)-1,1,1-trichloroethane	141	0.06	>1.0
2,2-bis-(*p*-methylphenyl)-1,1,1-trichloroethane	86– 88	0.03	>1.0
2,2-bis-(*p*-ethylphenyl)-1,1,1-trichloroethane (b.p. 184°–189° C. /1.5 mm. Hg.)	—	0.04	>1.0
2,2-bis-(*p*-methoxyphenyl)-1,1,1-trichloroethane	92	0.03	>1.0
2,2-bis-(*p*-nitrophenyl)-1,1,1-trichloroethane	165–167	>1.0	>1.0
2,2-bis-(*p*-hydroxyphenyl)-1,1,1-trichloroethane	195	>1.0	>1.0
2-*p*-chlorophenyl-2-*o*-chlorophenyl-1,1,1-trichloroethane	70– 72	(26% at 0.1)	>0.1
2-*p*-chlorophenyl-2-phenyl-1,1,1-trichloroethane	70– 73	0.25	>1.0
2,2-bis-(2,4-dimethylphenyl)-1,1,1-trichloroethane	106–109	>0.1	>0.1
2,2-bis-(2,5-dimethylphenyl)-1,1,1-trichloroethane	87– 89	>0.1	>0.1
2,2-bis-(3,4-dimethylphenyl)-1,1,1-trichloroethane	82	0.05	>0.1
2-(2,4-dimethylphenyl)-2-(*p*-chlorophenyl)-1,1,1-trichloroethane	50– 54	0.04	>0.1
2,2-bis-(2-methyl-4-chlorophenyl)-1,1,1-trichloroethane	99–100	>0.1	>0.1
2,2-bis-(4-chloro-3-nitrophenyl)-1,1,1-trichloroethane	145	>1.0	>1.0
2,2-bis-(4-chloro-3,5-dinitrophenyl)-1,1,1-trichloroethane	201–205	>1.0	>1.0
B.—*Changes in aromatic ring structure*			
2,2-bis-phenyl-1,1,1-trichloroethane	64– 65	1.0	>1.0
2,2-bis-naphthyl-1,1,1-trichloroethane	153–154	>0.1	>0.1
2,2-bis-(1-chloronaphthyl)-1,1,1-trichloroethane	197–212	>0.1	>0.1
2,2-bis-(2-chloronaphthyl)-1,1,1-trichloroethane	83– 88	>0.1	>0.1
2,2-bis-(thienyl-2)-1,1,1-trichloroethane	77	1.0	>1.0
2,2-bis-(2-chlorothienyl)-1,1,1-trichloroethane	61– 62	1.0	>1.0
2,2-bis-(2-bromothienyl)-1,1,1-trichloroethane	93– 94	>1.0	>1.0
2,2-bis-(2-methylthienyl)-1,1,1-trichloroethane	70– 71	>1.0	>1.0
C.—*Changes in aliphatic portion of DDT molecule*			
2,2-bis-(*p*-chlorophenyl)-1,1-dichloroethane	109–110	0.006	>1.0
2,2-bis-(*p*-chlorophenyl)-1,1-dichloroethylene	89	(24% at 1.0)	(39% at 1.0)
2,2-bis-(*p*-chlorophenyl)-1-chloroethylene	65– 67	>1.0	(45% at 1.0)
2,2-bis-(*p*-chlorophenyl)-ethylene	85– 87	>1.0	(82% at 1.0)
2,2-bis-(*p*-chlorophenyl)-ethane	53	(33% at 1.0)	(90% at 1.0)
2,2-bis-(*p*-chlorophenyl)-2,1,1,1-tetrachloroethane	91– 92	>1.0	>1.0
3,3-bis-(*p*-chlorophenyl)-2,1,1-trichloropropene (b.p. 181°–184° C./0.2 mm. Hg.)	—	>1.0	(38% at 1.0)
2,2-bis-(*p*-chlorophenyl)-1,1,1-trifluoroethane	60–61	(75% at 1.0)	(72% at 1.0)[2]
di-(*p*-chlorophenyl)-methane	54– 55	0.16	0.25
di-(*p*-chlorophenyl)-bromomethane	79– 80	(34% at 1.0)	>1.0
1,1-bis-(*p*-chlorophenyl)-1-chloroethane	76– 77	>1.0	(7% at 1.0)[2]
1,1-bis-(*p*-chlorophenyl)-1-bromoethane	84– 85	>1.0	>1.0
D.—*di-(p-chlorophenyl) compounds with oxygen in aliphatic portion*			
di-(*p*-chlorophenyl) ketone	145–146	(42% at 1.0)	>1.0
di-(*p*-chlorophenyl)-acetic acid	77– 78	>1.0	>1.0
di-(*p*-chlorophenyl)-acetic acid, ethyl ester	87– 88	>1.0	>1.0
di-(*p*-chlorophenyl)-methanol	92– 93	>1.0	>1.0
di-(*p*-chlorophenyl)-methanol, methyl ether	68– 69	(26% at 1.0)	(23% at 1.0)
di-(*p*-chlorophenyl)-methanol, ethyl ether	86– 88	(20% at 1.0)	>1.0
1,1-bis-(*p*-chlorophenyl)-ethanol	70– 71	1.0	0.1
1,1-bis-(*p*-chlorophenyl)-ethanol, methyl ether	83– 84	>1.0	(65% at 1.0)

Table 2.—(Continued)

Compound	Melting Point, Uncorrected ° C.	24-Hour Median Lethal Concentration, in Per Cent[1]	
		Greenhouse Thrips	Citrus Red Mite
E.—Replacement of $-CH_2$ group by other bivalent linkages			
di-*p*-chlorodiphenyl	138–142	(30% at 1.0)	>1.0
di-(*p*-chlorophenyl) ether (b.p. 310° C.)	—	>1.0	(57% at 1.0)
p-chlorobenzyl-*p*-chlorophenyl ether	81– 82	(73% at 1.0)	0.13
bis-(*p*-chlorophenoxy)-methane	70– 72	(69% at 1.0)	0.025
di-(*p*-chlorophenoxy)-ethane	129–131	(39% at 1.0)	(27% at 1.0)
di-(*p*-chlorophenoxy)-propane	117–119	>1.0	>1.0
di-(*p*-chlorophenyl) sulfide	90– 92	>1.0	(18% at 1.0)[3]
di-(*p*-chlorophenyl) selenide	96	(42% at 1.0)	>1.0
di-(*p*-chlorophenyl) sulfone	140–142	>1.0	>1.0
p-chlorophenyl-*p*-chlorobenzene sulfonate	79– 80	>1.0	>1.0
di-*p*-chloroazobenzene	183–184	>0.1	>0.1
di-*p*-chlorophenyl carbonate	142–143	(43% at 1.0)	>1.0
p-chlorobenzyl-*p*-chlorobenzoate	70– 71	(17% at 1.0)	1.0
N,N-bis-(*p*-chlorophenyl)-urea(300° subl.)	—	>1.0	>1.0
N,N-bis-(*p*-chlorophenyl)-thiourea	166–168	>1.0	>1.0
N,N-bis-(*p*-chlorophenyl)-methylene-diamine	62– 64	>1.0	>1.0
di-*p*-chlorostilbene	174–175	>1.0	>1.0
cis-alpha, 4,4′-trichlorostilbene	58– 59	(21% at 1.0)	(91% at 1.0)
trans-alpha, 4,4′-trichlorostilbene	94– 96	>1.0	(42% at 1.0)
1,2-(*p*-chlorophenyl)-1,2-dichloroethane	202–203	>1.0	>1.0
1,2-(*p*-chlorophenyl)-1,1,2,2-tetrachloroethane	189	>1.0	>1.0

[1] Figures in parentheses indicate percentage kill at concentration given.
[2] Kill in 48 hours, 100 per cent.
[3] Kill in 48 hours, 96 per cent.

pared with the substitution by chlorine, bromine, or iodine; and that carbon atoms with two or more fluorine atoms attached are very stable (McBee 1947). Thus we should expect 2,2-bis-(*p*-chlorophenyl)-1,1,1-trifluorethane (m.p. 60°–61° C.) to be more similar chemically to 2,2-bis-(*p*-chlorophenyl)-ethane (m.p. 52°–53°) than to 2,2-bis-(*p*-chlorophenyl)-1,1,1-trichloroethane (DDT, m.p. 108°–109°). This is corroborated by the close similarity in melting points and biological action of the trifluoro compound and the ethane, and their diversity from DDT.

The compound di-(*p*-chlorophenyl)-methane is also of especial interest because of its high toxicity to both mites and thrips, which makes it unique among the compounds studied. It is possible, therefore, that the di-substituted methane group, unencumbered by chlorine or carbon atoms, is well suited to penetrate both insect and mite integument.

Table 2, section D, indicates a further departure from the DDT type of structure by a modification of the aliphatic portion of the molecule to include oxygen-containing groups such as alcohols, ethers, ketones, carboxylic acids, and esters. Many of these compounds show slight acaricidal activity, which reaches a maximum in 1,1-bis-(*p*-chlorophenyl)-ethanol. This compound, which is a promising acaricide, is relatively slow-acting and results in a curious paralysis of the mite. It is of interest that the related bis-(*p*-chlorophenyl)-methanol is nearly inactive, and that replacement of the hydroxyl groups of both these compounds by the methyl or ethyl ethers or by halogen results in diminished activity. With several of these materials, the mites were severely affected within 24 hours; counts were also taken in 48 hours, as indicated in the tables. The maximum effectiveness of 1,1-bis-(*p*-chlorophenyl)-ethanol appears to be exerted only after several days.

Data from the use of compounds having other bivalent linkages between the aromatic rings are shown in table 2, section E. Acaricidal activity reached a maximum with bis-(*p*-chlorophenoxy)-methane, which was the most effective acaricide studied against the citrus red

mite (Jeppson 1948). Definite acaricidal activity was shown by di-(*p*-chlorophenyl) ether, di-(*p*-chlorophenyl) sulfide, *p*-chlorobenzyl-*p*-chlorophenyl ether, and *p*-chlorobenzyl-*p*-chlorobenzoate. Elongation of the aliphatic chain to produce di-(*p*-chlorophenoxy)-ethane and di-(*p*-chlorophenoxy)-propane resulted in inactivity.

Table 3 indicates the relative effectiveness of changes in the aromatic substituents of bis-(*p*-chlorophenoxy)-methane and in *p*-chlorobenzyl-*p*-chlorophenyl ether. The di-*p*-chloro substituents were the most toxic, followed in order by di-*p*-Br, and di-*p*-CH_3; di-*p*-NO_2 and di-*p*-OCH_3 were ineffective. This is in agreement with the order of effectiveness of the corresponding DDT substituents shown in table 1, except for the inactivity of the di-*p*-OCH_3 compound. These data add further support to a hypothesis that maximum acaricidal activity in these compounds is associated with the presence of the di-(*p*-chlorophenyl) linkage. In the benzyl-phenyl ethers, asymmetry introduced by a *para* substituent other than chlorine, or by the presence of chlorine in *ortho* positions, resulted in greatly decreased acaricidal action. An interesting feature of this series is the definite activity of *p*-chlorophenyl-benzyl ether and the low activity of its isomer, *p*-chlorobenzyl-phenyl ether. It will be noted that the more active isomer is the one more closely related to bis-(*p*-chlorophenoxy)-methane.

Table 3.—Effects of various ring substituents on toxicity of di-phenoxymethanes and phenylbenzyl ethers to the greenhouse thrips and citrus red mite.

Compound	Melting Point, ° C.	24-Hour Median Lethal Concentration, in Per Cent[1]	
		Greenhouse Thrips	Citrus Red Mite
bis-(*p*-chlorophenoxy)-methane	70– 72	(69% at 1.0)	0.025
bis-(*p*-bromophenoxy)-methane	74– 75	>1.0	0.1[2]
bis-(*p*-methylphenoxy)-methane	40	>0.1	0.09
bis-(*p*-nitrophenoxy)-methane	139–140	>0.1	>0.1
bis-(*p*-methoxyphenoxy)-methane	47– 49	>1.0	>1.0
p-chlorobenzyl-*p*-chlorophenyl ether	81– 82	(73% at 1.0)	0.13
p-chlorobenzyl-*p*-bromophenyl ether	96– 98	(15% at 1.0)	0.9
p-chlorobenzyl-*p*-methylphenyl ether	91– 92	(27% at 1.0)	(22% at 1.0)
2,4-dichlorobenzyl-*p*-chlorophenyl ether	70– 71	(60% at 0.9)	(27% at 0.9)[3]
p-chlorobenzyl-2,4-dichlorophenyl ether	68	(24% at 1.0)	(28% at 1.0)
2,4-dichlorobenzyl-2,4-dichlorophenyl ether	101–104	>1.0	>1.0
p-chlorobenzyl-pentachlorophenyl ether	157–160	>1.0	>1.0
p-chlorobenzyl-*p*-nitrophenyl ether	111–113	>1.0	>1.0
p-chlorobenzyl-*p*-methoxyphenyl ether	84	>1.0	>1.0
p-chlorobenzylphenyl ether	84– 86	(24% at 1.0)	(24% at 1.0)
p-chlorophenylbenzyl ether	70– 73	(62% at 1.0)	(82% at 1.0)[4]
4-chlorobenzyl-2-chlorophenyl ether	69	(17% at 1.0)	(18% at 1.0)
benzyl-2,4-dichlorophenyl ether	59– 60	(28% at 1.0)	(100% at 1.0)
3,4-dichlorobenzyl-4-chlorophenyl ether	48– 50	(14% at 1.0)	(85% at 1.0)
benzylphenyl ether	38– 39	(98% at 1.0)	>1.0

[1] Figures in parentheses indicate percentage kill at concentration given.
[2] Kill in 48 hours, 96%.
[3] Kill in 48 hours, 85%.
[4] Kill in 48 hours, 100%.

Table 4 presents data on some related compounds containing a single *p*-chlorophenyl group. Only one compound, 2-(*p*-chlorophenyl)-1,1,1-trichloroethanol, was appreciably toxic, but it proved to be one of the most effective materials studied as an acaricide. Structurally it somewhat resembles the active 1,1-bis-(*p*-chlorophenyl)-ethanol.

In order to see if there were marked variations in the effectiveness of certain of these compounds against various species of mites, several of the most active were similarly tested against *Tetranychus bimaculatus*. The results appear in table 5. It will be noted that 1,1-bis-(*p*-chlorophenyl)-ethanol was about three times as

Table 4.—Toxicity of compounds containing a single p-chlorophenyl group to greenhouse thrips and citrus red mite.

Compound	Melting Point, ° C.	24-Hour Median Lethal Concentration, in Per Cent[1]	
		Greenhouse Thrips	Citrus Red Mite
p-chlorophenol	39– 40	(16% at 1.0)	>1.0
p-chlorobenzyl alcohol	73	(19% at 1.0)	>1.0
2-(*p*-chlorophenyl)-1,1,1-trichloroethanol (b.p. 165°–175° C./2 mm. Hg.)	—	1.0	0.2
p-chlorobenzyl chloride	218–220	>1.0	>1.0
p-chloroanisole (b.p. 84°–87° C./18 mm. Hg.)	—	(18% at 1.0)	>1.0
p-chlorophenetol	16– 17	>1.0	(11% at 1.0)
p-chloroacetophenone	12– 14	(14% at 1.0)	>1.0
p-chloro-bromoacetophenone	92– 93	0.3	(62% at 1.0)
p-chlorophenoxyacetic acid	156–158	>1.0	>1.0
p-chlorophenylallyl ether (b.p. 230° C.)	—	(34% at 1.0)	>1.0
p-chlorobenzaldehyde	44– 47	>1.0	>1.0
p-chlorobenzoic acid	238	(44% at 1.0)	>1.0

[1] Figures in parentheses indicate percentage kill at concentration given.

toxic to *T. bimaculatus* as to *Paratetranychus citri*, while with bis-(*p*-chlorophenoxy)-methane the converse was true, this compound being about forty times as effective against *P. citri* as against *T. bimaculatus*. Such differences have also been indicated in field tests with these two compounds against *P. citri* and *T. bimaculatus*. These data show the importance of specificity in acaricides and point to the necessity of testing new materials on species of economic importance.

Most of these compounds involving di-*p*-chlorophenyl groups are inherently stable. This contributes to a long-lasting residual action. For example, residues from 1 per cent 1,1-bis-(*p*-chlorophenyl)-ethanol and 1 per cent bis-(*p*-chlorophenoxy)-methane applied to oranges on trees by the dipping method described above, were still lethal to adult *Paratetranychus citri* after 2 months' outdoor exposure. This property in conjunction with the high degree of specific action and the low mammalian and plant toxicity of the materials makes them nearly ideal toxicants.

In attempting to explain the acaricidal action of the compounds studied in this paper it is difficult to reconcile the two classical theories of the mode of action of DDT with the results obtained. Laüger *et al.* (1944) conclude that the trichloromethyl group of the DDT molecule serves as a lipid-solubilizing agent, and that the di-*para*-chlorophenyl group is the toxophoric agent. Martin & Wain (1944) have taken an opposing view in suggesting that the *para*-chlorophenyl groups are responsible for lipid solubility, and that the trichloromethyl group is the toxophoric group which acts by virtue of liberating hydrogen chloride *in vivo*.

The tetranychid mites as far as has been demonstrated possess the same general type of cuticle and nervous system as the insects. Furthermore, they respond to other well-known categories of insecticides, such as the dinitrophenols and the organic phosphates, in a manner indistinguishable from most insects. Therefore, the writer feels that any acceptable theory of the mode of action of DDT should account for the anomalies observed, namely: (1) the complete inactivity of DDT as an acaricide, and (2) the marked effectiveness of such compounds as 2,2-bis-(*p*-chlorophenyl)-ethane, 2,2,-bis-(*p*-chlorophenyl)-1,1,1-trifluoroethane, di-(*p*-chlorophenyl)-methane, 1,1-bis-(*p*-chlorophenyl)-ethanol, *p*-chlorobenzyl-*p*-chlorophenyl ether, and

Table 5.—Relative toxicity of four acaricides to two species of mites, *Paratetranychus citri* and *Tetranychus bimaculatus*.

Compound	24-Hour Median Lethal Concentration, in Per Cent	
	P. citri	*T. bimaculatus*
1,1-bis-(*p*-chlorophenyl)-ethanol	0.1	0.035
bis-(*p*-chlorophenoxy)-methane	0.025	>1.0
bis-(*p*-chlorophenyl)-methane	0.25	0.25
2-(*p*-chlorophenyl)-1,1,1-trichloroethanol	0.2	0.4

bis-(*p*-chlorophenoxy)-methane. None of these active compounds meets the requirements of either theory. They do not possess the "lipid-solubilizing" trichloromethyl group of Laüger *et al.* (1944) or the "dehydrohalogenating" toxophoric group of Martin & Wain (1944). Yet all of them possess in common the di-(*p*-chlorophenyl) group, and it has been shown that any alteration in this relationship of the aromatic chlorine atoms, or the replacement by other aromatic substituents, results in a decided decrease in toxicity.

SUMMARY AND CONCLUSIONS.—Approximately 100 organic compounds more or less closely related to DDT were tested for acaricidal activity against the citrus red mite, *Paratetranychus citri* (McG.), and for insecticidal activity against the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), by exposure to equivalent residues on Valencia oranges, for the purpose of obtaining comparisons between the structural requirements for acaricidal vs. insecticidal activity. The following conclusions were reached:

1. DDT and all the related trichloroethanes with varying *para-para'* substituents studied, most of which showed insecticidal activity, had no acaricidal action.

2. Alterations in the ring structure of the aromatic trichloroethanes to include naphthyl, chloronaphthyl, thienyl, chlorothienyl, methylthienyl, and bromothienyl resulted in greatly decreased insecticidal action.

3. Alterations in the trichloroethane portion of the DDT molecule resulted in decreased insecticidal action, but in increased acaricidal activity in the order:

$$\begin{matrix} R \\ | \\ HCCCl_3 \\ | \\ R \end{matrix} < \begin{matrix} R \\ | \\ C{=}CCl_2 \\ | \\ R \end{matrix} < \begin{matrix} R \\ | \\ C{=}CHCl \\ | \\ R \end{matrix} < \begin{matrix} R \\ | \\ C{=}CH_2 \\ | \\ R \end{matrix} < \begin{matrix} R \\ | \\ HCCF_3 \\ | \\ R \end{matrix} = \begin{matrix} R \\ | \\ HCCH_3 \\ | \\ R \end{matrix} < \begin{matrix} R \\ | \\ CH_2, \\ | \\ R \end{matrix}$$

where R = *p*-chlorophenyl.

4. Di-(*p*-chlorophenyl)-methane proved effective, both as an insecticide and as an acaricide, and was unique in this regard among the compounds studied.

5. The acaricidal effectiveness of 2,2-bis-(*p*-chlorophenyl)-ethane and of 2,2-bis-(*p*-chlorophenyl)-1,1,1-trifluoroethane appears to indicate that Laüger's theory (1944) that lipid solubility is conferred on the DDT molecule by the trichloromethyl group is not applicable to acaricides. Therefore, it is probable that there are distinct physiological differences in the insect and mite integument and/or nervous system.

6. In a series of compounds related to DDT but possessing oxygen atoms in the aliphatic portion of the molecule, 1,1-bis-(*p*-chlorophenyl)-ethanol possessed outstanding acaricidal effectiveness. The activity of this compound was lost by ether formation, by replacement of hydroxyl by chlorine, or by removal of the methyl group.

7. Acaricidal activity was found in di-(*p*-chlorophenyl) ether, di-(*p*-chlorophenyl) sulfide, *p*-chlorobenzyl-*p*-chlorophenyl ether, *p*-chlorobenzyl-*p*-chlorobenzoate, and reached a maximum in bis-(*p*-chlorophenoxy)-methane.

8. The order of acaricidal effectiveness in *para-para'* substituents of bis-phenoxymethane was $Cl < Br < CH_3 < NO_2 < CH_3O$. In the related benzyl-phenyl ethers, substitution of chlorine in other than the *para-para'* positions resulted in greatly decreased acaricidal action. This maximum effectiveness associated with the *para-para'*-chlorophenyl groups is, of course, a characteristic of DDT insecticides. This conforms to the Laüger theory (1944) that the di-*para*-chlorophenyl group is a toxophore.

9. In a series of compounds containing a single *p*-chlorophenyl group, only 2-(*p*-chlorophenyl)-1,1,1-trichloroethanol showed any insecticidal or acaricidal effectiveness.

10. The relative effectiveness of the two most effective acaricides included in this series, bis-(*p*-chlorophenoxy)-methane and 1,1-bis-(*p*-chlorophenyl)-ethanol, on *Paratetranychus citri* and *Tetranychus bimaculatus* Harvey was 40 to 1 for the former and 1 to 3 for the latter. This indicates that a marked degree of specificity is found in acaricides.

11. One per cent residues of 1,1-bis-(*p*-chlorophenyl)-ethanol and bis-(*p*-chlorophenoxy)-methane deposited on oranges on trees were still lethal to *Paratetranychus citri* after two months' outdoor exposure.

12. The acaricidal behavior of the compounds studied is difficult to interpret according to the classical theories of the mode of action of DDT and related compounds, viz. those of Lauger *et al.* (1944) and of Martin & Wain (1944).

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Resistance of the Pawnee Wheat Variety to Hessian Fly Under Kansas Conditions[1]

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Pawnee wheat was distributed to farmers in Kansas and Oklahoma in 1943 and in Nebraska in 1942. The cross which resulted in Pawnee was made to combine the hessian fly resistance and other good qualities of Kawvale with the bread-making and other qualities of Tenmarq. The testing of the progeny of this cross was the work of several State agricultural experiment stations and the United States Department of Agriculture. The study of hessian fly resistance was made jointly by the Kansas Agricultrual Experiment Station and the Bureau of Entomology and Plant Quarantine.

REVIEW OF LITERATURE.—The results of a study of the hessian fly resistance of Pawnee, C. I. 11669, and its resistant parent, Kawvale, made from 1924 until its release to farmers have been reported (Painter & Jones, 1945). These studies showed: "The value of Pawnee is a result of both tolerance and resistance to the fly in central Kansas and is shown by (1) a 50 per cent lower infestation than the susceptible variety Tenmarq, as measured by

[1] Contribution No. 560 of the Department of Entomology Kansas Agricultural Experiment Station, Manhattan, Kans. Investigations conducted cooperatively by the Department of Entomology and the Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture.

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[4] Thanks are due to members of the Departments of Agronomy and Botany, Kansas Agricultural Experiment Station, for assistance in various phases of this investigation, especially for permission to use the data on acreage of Pawnee sown in earlier years and for samples from the cooperative variety tests.

percentage of plants infested; (2) approximately a 75 per cent lower tiller infestation, as compared with the susceptible variety Tenmarq; (3) a decrease in the size of puparia and a decreased rate of development, and perhaps other biological differences; (4) comparatively low fly injury to infested plants, especially in the fall, and to individually infested tillers in both fall and spring; and (5) an excess in yield in comparison with Tenmarq, up to more than twice as much as the latter variety under heavy fly infestation. In evaluating the hessian fly resistance of Pawnee, it is necessary to consider all these factors." The above statements apply only to central Kansas. Painter & Jones also reported evidence that the population of fly able to feed on Pawnee is increasing.

The agronomic and disease resistance characteristics of Pawnee are also unique. In addition to its resistance to some races of leaf and stem rust, moderate resistance to bunt, and high resistance to loose smut, in 42 tests in different localities and years (1937-42) in Kansas, Pawnee had an advantage in yield of 17 per cent above Tenmarq, until 1947 the most widely grown winter wheat variety in the state. These results were in the absence or near absence of hessian fly (Reitz & Laude, 1943). In addition to its innate yielding capacity, Pawnee has a good test weight, stiff short straw, is winter hardy, and matures early. The milling and baking qualities are similar to those of Turkey wheat.

A recent variety survey of Kansas wheat (Collins 1947) showed that in the fall of 1946 Pawnee was the leading variety, occupying 24.7 per cent of the wheat acreage of the state. The data from that report have been plotted on a map giving the percentage of the wheat acreage planted to Pawnee in each county (Fig. 1). Pawnee is the predominating variety in the eastern half of the state. Nemaha county, with 89 per cent, and Reno and Shawnee, with 82 per cent, were planted with the highest proportion of Pawnee. The small acreage of Pawnee in western Kansas and the small total acreage of any wheat in the eastern third of the state resulted in about 76 per cent of the total acreage of Pawnee in the central third of Kansas. In this area Pawnee is resistant to hessian fly, and this insect has been especially important.

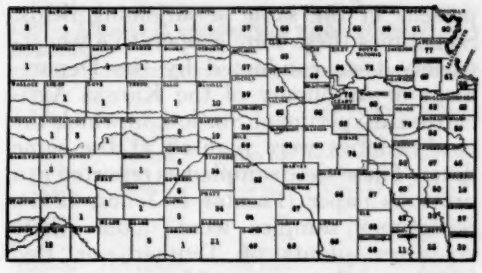

FIG. 1.—Numerals in each county show percentage of entire wheat acreage planted to Pawnee wheat in each county of the state for crop of 1946–47. (From U. S. Dept. Agr. wheat variety survey, 1947.)

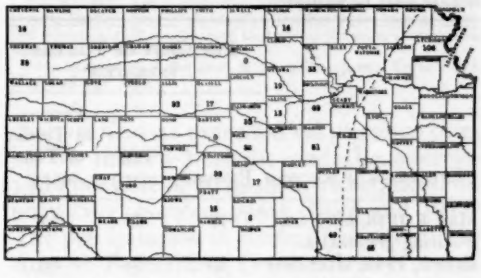

FIG. 2.—Infestation of Pawnee wheat, 1946 and 1947, in terms of per cent of stem infestation of susceptible wheat, usually Tenmarq in the same farmer's field. The variety Pawnee in previous tests has shown less resistance east of the broken line.

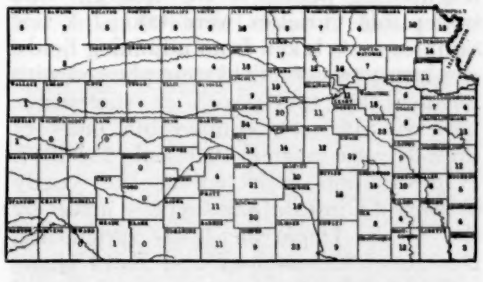

FIG. 3.—The area of severe and frequent infestation of hessian fly where large wheat acreages are grown lies in central Kansas. Numerals in counties show average per cent of stems infested by spring generations of hessian fly in each of two or more years in 1944, 1945, and 1946.

MATERIALS AND METHODS.—The purpose of this study was to examine as far as possible the behavior of hessian fly on Pawnee wheat under farm conditions and the effect of the planting of this variety on the fly population. During May and June of 1946 and 1947 efforts were made to locate central and western Kansas wheatfields infested by fly in which Pawnee and an identifiable susceptible variety were

present in the same or adjoining fields. Sometimes these were cooperative wheat-variety tests conducted by the Department of Agronomy of the Kansas Agricultural Experiment Station, in which the two varieties were planted at the same dates. These were sampled as reported in a previous paper (Painter & Jones, 1945). Sometimes samples were taken where volunteer plants of Tenmarq or Red Chief or other susceptible variety were present in a field of Pawnee. In such cases neighboring plants of the resistant and susceptible varieties were taken. A few samples were taken from adjoining fields, or where parts of a field were planted with Pawnee and part with a susceptible variety. Six such comparable pairs of samples were taken in 1946 and 22 in 1947.

Table 1.—Hessian fly infestations of Pawnee and Tenmarq on succeeding dates at Rice County Cooperative Tests, each representing a single pair of samples.

Conditions of Record	Per Cent of Tillers Infested		
	Pawnee	Tenmarq	Pawnee in Terms of Tenmarq[1]
May 4, 1946, after first spring generation	10	68	15
June 7, 1946, after two spring generations	25	83	30
June 6, 1947, after two spring generations	24	66	36

[1] Percentage rating of Pawnee if Tenmarq were rated at 100

Information collected in the yearly hessian fly infestation surveys made by the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine has been used in some phases of this study.

Results and Discussion.—The data derived from the paired samples discussed above are given in figure 2, in which the infestation of Pawnee is expressed in percentage of the infestation of the susceptible variety. Where more than one sample was taken in a county the results were averaged. In 27 of the 28 paired comparisons, Pawnee had considerably lower infestation than did the susceptible variety. The single case in which this was not true occurred in Atchison County in an area where Pawnee is known to be less resistant. If these data are compared with data gathered before the release of Pawnee to farmers and reported (Painter & Jones 1945), there is little indication of a change in the infestation status.

In Rice County (Table 1) where infestation records were taken in 1947 within half a mile of the area where records were taken in 1946, the records may show some tendency for an increase in the fly population capable of feeding on Pawnee. The Manhattan fly nursery records also appear to indicate an increase in such strains of fly; but, since flaxseeds for infesting the nursery have been brought in from various localities in central Kansas, the data are difficult to interpret. They suggest the need for study of hessian fly populations that occur naturally over a period of several years in several localities, to determine whether such changes in population are tending entirely in one direction.

In the course of the 1947 hessian fly infestation survey, the identity of the variety could be determined from plant characters in somewhat less than half of the wheat samples. The remaining samples were largely mixed varieties, those taken after harvest, or after hail damage, or of varieties that could not be named with certainty because of other conditions. In table 2 are given the survey records from the 16 counties in central Kansas in which collections were made from at least two fields each of Pawnee and a susceptible variety. In contrast to the pairs of samples reported above, these fields were mostly rather widely separated. The infested tillers in individual fields ranged from 0 to 52 per cent in Pawnee and from 0 to 98 per cent among susceptible varieties. This wide variation is probably due to the local variation in intensity of infestation resulting from such factors as date of planting, previous fly populations, proximity of infested volunteer and stubble from last year, and other factors. Notwithstanding such variation, the average infestation of Pawnee was less than that of susceptible varieties in each county. The average infestation for the 58 Pawnee fields was 8 per cent, and in the 62 susceptible fields 25 per cent of the tillers were infested.

This difference may arise in part from the fact that somewhat fewer eggs are laid on Pawnee, at least under nursery conditions. Whether this occurs on a field

Table 2.—Hessian fly infestation in samples of identifiable wheat varieties, 1947 survey.

County	Pawnee		Susceptible Varieties[1]	
	Samples	Average Per Cent of Infested Stems	Samples	Average Per Cent of Infested Stems
South Central Kansas:				
Barton	3	3	3	17
Harvey	3	1	2	10
Kingman	3	2	3	23
Marion	6	22	8	56
McPherson	2	27	3	33
Pratt	3	4	4	25
Rice	4	22	8	41
Stafford	3	6	2	29
Total (8 counties)	27	—	33	—
Average	—	12	—	36
North Central Kansas:				
Clay	2	4	2	18
Cloud	3	0	2	6
Dickinson	4	16	6	20
Ellis	3	3	3	4
Osborne	6	1	2	1
Ottawa	9	2	6	10
Rooks	2	0	4	7
Saline	2	2	4	25
Total (8 counties)	31	—	29	—
Average	—	4	—	13
Total, central Kansas	58	—	62	—
Average, central Kansas	—	8	—	25

[1] Mostly Tenmarq and Red Chief.

Table 3.—The yearly increase of Pawnee acreage in Kansas in comparison with hessian fly infestation.

Crop Year	Total Acres of Winter Wheat Sowed	Acres of Pawnee Sowed	Average Per Cent of Stems Infested by Hessian Fly in Kansas	
			South Central[1]	North Central[2]
1942–43[3]	10,735,000	27[4]	8.1	9.2
1943–44	13,097,000	723[4]	6.2	14.6
1944–45	14,145,000	40,000[4]	12.5	15.1
1945–46	14,149,000	800,000[4]	21.9	10.6
1946–47	14,994,000	3,700,000[5]	16.0	7.0

[1] 76 per cent of the state acreage of Pawnee is in the central third of Kansas.

[2] Yearly hessian fly infestation surveys, U. S. Dept. Agr. reports. Each average is based on over 50 and many are based on 100 samples.

[3] Year of release to Kansas farmers.

[4] U. S. Dept. Agr. Cooperative hard red winter wheat regional reports for the years 1943–46. The first two years include certified wheat only. It is estimated that about the same acreage was planted from noncertified seed.

[5] On basis of 24.7 per cent of 15 million acres. Kans. State Board of Agr. Rpt.

scale is not known and is believed to be a minor factor. A larger share of the difference in infestation here recorded is due to the fact that a considerable proportion of the hessian fly larvae that reach the feeding position on Pawnee fail to grow and mature (Painter & Jones 1945, p. 134). The data suggest that perhaps two-thirds of the larvae reaching the feeding position on Pawnee did not mature. In an area such as Reno County where 82 per cent of the wheat consisted of the variety Pawnee, the fly larvae thus destroyed as a result of planting this variety must have been considerable.

There is still another set of data that indicate an effect of Pawnee on the fly population. The distribution of fly in Kansas in 1944, 1945, and 1946 as recorded in the hessian fly infestation survey (Cartwright, 1943-47) is indicated in figure 3. These figures when studied by years also indicate a developing outbreak of fly in central Kansas. McColloch (1923) wrote: "Those conditions most favorable to the growing of wheat are also most favorable to the development of the fly". Similar observations have been made by other workers. The 1946-47 environmental factors were certainly most favorable for both wheat and fly, for the 1947 wheat crop in Kansas exceeded all previous ones by 34 million bushels, and the average yield per acre of 20 bushels was equaled on only two previous years, 1882 and 1914. The precipitation in central Kansas during August, September, October, and November of 1946 and March, April, May, and June of 1947 exceeded the previous average for each of these months. The temperature was below average in August and September 1946, and in May and June 1947, but above average for October and November 1946. All these environmental

FIG. 4.—Hessian fly infestation and injury to strains of wheat in Manhattan Nursery, Nov. 13, 1946. Each small stake indicates an infested wheat plant. Row 552 Tenmarq, 95 per cent of plants infested; 33 per cent of infested plants died by Nov. 30, 1946. Row 551 Pawnee, 65 per cent of plants infested; none of infested plants dead by April 1947. Row 553 Kawvale-Marquillo×Kawvale-Tenmarq C. I. 12128, 11 per cent of plants infested; none died during winter. The difference shown here between Pawnee and Tenmarq occurred on a field scale in central Kansas in 1946.

conditions should have been highly favorable for the development of hessian fly where it was present in sufficient abundance to take advantage of conditions. Yet in 19 of the 23 counties in central Kansas for which data are available there was a decrease in infestation in 1946-47 compared with the averages of the three previous years.

The estimated yearly increase in the acreage of Pawnee, in comparison with the fly population in the central area of Kansas, is shown in table 3. The average fly infestation in south-central Kansas dropped about one-third in 1947, although all known environmental conditions except varietal composition would lead one to expect an increase. The decline, which began earlier in north than in south-central Kansas, may be related to the earlier distribution of Pawnee in Nebraska. Direct information on this point is not available. Pawnee wheat was apparently responsible for part of the decrease in fly population in central Kansas in 1947.

In the crop year 1945-46 there was considerable loss of stand of susceptible varieties in some areas, owing to the killing of plants by hessian fly (Fig. 4). Many of these thin fields of susceptible varieties were plowed under in May, but nearby fields of Pawnee gave average or better than average yields for the community. Such evidence of the superiority of Pawnee at various points in central Kansas, owing to its resistance to fly, was an important reason for the widespread planting of the variety.

CONCLUSIONS.—The fly resistance of the Pawnee variety of wheat has been clearly evident in most areas and has contributed to the rapid use and acceptance of this variety in central Kansas, as found by the Bureau of Entomology and Plant Quarantine and the Kansas Agricultural Experiment Station.

The evidence presented also indicates that the fly resistance of Pawnee has held up well under farm conditions. There has been some evidence that the population able to infest Pawnee has increased in some areas, but more data, taken over a longer period, are required to establish this fact.

Evidence indicates that, in the area where it is resistant, Pawnee may have been responsible for a general reduction of the fly population. This has occurred because a considerable proportion of the larvae that reach the feeding position on Pawnee plants do not mature.

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Control of the Red-banded Leaf Roller[1]

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The red-banded leaf roller, *Argyrotaenia velutinana*, Wlkr., has suddenly became the most destructive insect pest of apples in the Shenandoah-Cumberland fruit belt. Prior to the current outbreak it had not been considered a major pest of the fruit industry in this belt. The standard arsenate of lead spray schedule has been considered effective in the control of this pest. With the advent of DDT and its replacement of arsenate of lead in the spray schedule there has been a steadily-increasing buildup in leaf roller population throughout the fruit belt. Prior to 1948 the outbreaks had been localized in widely scattered orchards throughout the area but there has been a gradual increase until during the current season, 1948, the outbreak has been wide spread. A general survey showed damage ranging from light to very severe with an average of near 50 per cent of the crop injured.

The reasons for this serious outbreak of leaf roller are not clearly apparent. It is believed to be due in part at least to the extensive use of DDT which may have destroyed many of the parasites and other natural enemies which in the past have aided in the control of this pest. But there are many reasons to believe that this serious outbreak is not due entirely to the use of DDT. This belief is well supported by the wide distribution of the pest in this outbreak. It could readily be found in great abundance on practically all types of vegetation even in places far removed from areas where DDT had been used. This fact tends to suggest the possibility that it may be a cyclic outbreak due to natural factors rather than to the wide use of DDT. In commerical orchards, however, the omission of arsenate of lead from the regular spray schedule during recent years had been a major factor in the heavy losses caused by the pest.

The present outbreak was anticipated early in the season of 1948. Early activity of first brood moths was striking during the last week of March and the first week of April. Bait pail records showed extremely heavy moth activity during most of the month of April. In view of this information extensive test plots were set up in heavily infested orchards and gratifying results obtained. Results from these early season tests against first brood larvae served as a basis for further tests against second and third brood larvae.

METHOD.—The plot system followed in all first brood work was a randomized distribution of single-tree plots with five replications. In general, the second and third brood work was conducted in single-tree plots without replication. All sprays were applied with two 8-nozzle guns equipped with No. 4 discs; one from a tower on top of the sprayer tank and the other from the ground. They were operated from a standard orchard sprayer with a 35-gallon per minute pump developing a pressure of 600 pounds. An entire tree was sprayed in one operation by driving completely around it. Approximately 50 gallons of diluted spray was applied per tree per application. Most of the experiments were conducted in blocks of 35-year-old Stayman trees.

Leaf roller infestation records were taken by time-limit examinations of the foliage and by examination of a random sample of 200 fruits from each plot tree at harvest time. Fruit records were taken only in the plots where full season spray schedules had been applied. Records were taken at the end of first brood activity by time-limit examination of each tree. A period of thirty minutes per tree was spent collecting fruit and foliage for larvae and pupae. Half of this time was spent collecting from the ground and the other half from within the tree. All infested fruits and foliage thus collected were brought into the laboratory for examination for larvae and pupae. This was a laborious method, requiring an average of approximately eight hours per treatment, but the accuracy of the results seem to justify the effort. Second and third brood records were taken in the same manner except that examinations were made in the field at time of collections. Fruit infestation records were taken at harvest time. However, such records have not proven too accurate for measuring the ef-

[1] "Published with the approval of the Director as Scientific Paper No. 400 of the West Virginia Agr. Exp. Station."

fectiveness of a given treatment because of variation in yield and fruiting habit of different varieties. Furthermore, much of the damage caused by first brood larvae is noted very early in the season in the form of a heavy drop following the petal-fall period, the so-called "June drop." Small fruits injured at this stage of development soon fall.

RESULTS.—Successful early season tests indicated that at least three new materials were extremely effective in the control of first brood leaf roller larvae. The most effective materials tested against first brood larvae were dichlorodiphenydichloroethane[1], chlorinated camphene[2] and parathion. Other materials, such as arsenate of lead and DDT, gave a fairly high degree of control but were not equal to the ones named above nor did they give satisfactory control, at practical concentrations, in heavy infestations such as those existing in the orchards where these experiments were conducted.

DICHLORODIPHENYL DICHLOROETHANE.—This material in liquid form was by far the most effective material tested in the experiments for the control of the red-banded leaf roller. The results indicate that the minimum effective concentration of this material is about eight ounces (one quart of 25 per cent concentrate) per 100 gallons of diluted spray; however, concentrations as low as four ounces gave a very high degree of control. The liquid form was much more effective than the powder form. It requires about two pounds of the 50 per cent wettable powder to equal one quart of the 25 per cent liquid concentrate. The maximum effectiveness of the material results from its control of the larvae; therefore it should be applied when the maximum number of larvae are present. The proper use of the liquid form will eliminate all hazard of leaf roller damage. A single application properly applied will practically destroy any leaf roller population.

The liquid dichlorodiphenyl dichloroethane gave striking results not only in the control of first brood larvae but also in the control of those of the second and third broods. In the full season schedule it was used at the rate of 3 pints in the petal-fall and one quart in the first and second cover sprays before results were checked showing complete control. This schedule was continued with the use of one quart in each of the third, fourth and fifth cover sprays with continued effective control. Moth migration in single-tree plot experiments tends to level off populations and thus mask the effectiveness of differential treatments; however, the insecticide was so effective that second brood records showed only 96 larvae and pupae for the trees. Harvest results in this plot also showed only 0.3 per cent of the fruit damaged by leaf roller.

The effectiveness of liquid rhothane appeared to be due to its high degree of penetration. Other materials such as toxaphene, parathion, arsenate of lead and DDT were definitely toxic to leaf roller larvae but were much less effective than the liquid dichlorodiphenyl dichloroethane because of the protective feeding habits of the larvae. During the early season, normal vegetative growth is very rapid, especially the foliage on vigorous water sprouts. Within a few days after toxic sprays have been applied this vigorous growth has produced ample new foliage, free from toxic sprays, for larval survival. This material, however, readily penetrates the webs and reaches the larvae in their protective shelters.

On the basis of early season results the liquid form was recommended for general commercial use and was used on several thousand acres of orchards with excellent results. Even where relatively poor jobs of spraying were done the results were very striking. As soon as it comes in contact with the webbing it seems to dissolve and loosen it. The larvae then become very active leaving their protective shelters and dropping from the trees on web streamers. Within a few minutes after the spray was applied a large percentage of the larvae had left their webbed leaves and other protected places and dropped on their streamers. Many of them remained thus suspended on their webs for several hours but none were observed to be able to regain the tree. All of those watched eventually dropped to the ground but none were able to move far. Many of them remained relatively inactive for several hours before they died or were destroyed by predators. Large numbers were placed in rearing jars with unsprayed foliage

[1] Rohm-Haas Company's Rhothane.
[2] Hercules Powder Company's Toxaphene.

where many of them remained alive for several days but with no indication of feeding.

Dichlorodiphenyl dichloroethane appears to be safe for use on fruit and foliage and is compatible with most insecitcides, acaricides and fungicides with the exception of DN–111. Its compatibility with sulphur in the early season sprays was questioned but during the past two seasons it has been used with flotation sulphur in the petal-fall and first and second cover sprays without definite indications of injury. Some of the plot-trees showed slight chlorosis of foliage but this was not consistent nor was it definite.

Miscellaneous studies indicate that liquid dichlorodiphenyl dichloroethane is also toxic to adult moths. It also appears to retain a rather high degree of residual toxicity to larvae for a period of 10 days to 2 weeks following the time of application, depending on the concentration used. It showed little toxicity to the pupae.

TOXAPHENE.—Toxaphene was also very effective in the control of the red-banded leaf roller. This material was used in a full-season schedule of a petal-fall and five cover spray applications at the rate of one pound of taxicant in 100 gallons of diluted spray. First brood control counts were made following the second cover spray. These showed only 12 larvae and pupae for the five trees. This count had only increased to 173 larvae and pupae by the end of the second brood with an infestation at harvest of only 5.1 per cent. This material was extremely toxic to leaf roller larvae and was not injurious to fruit and foliage.

PARATHION.—Parathion was one of the more toxic materials tested in these experiments for the control of the red-banded leaf roller. This material was more effective in the control of first brood larvae than for later broods. When used at concentrations as low as one ounce of toxicant per 100 gallons in the petal-fall and first and second cover sprays the control of first brood larvae was excellent; however there was a slight increase in control with increase in concentration up to four ounces per 100 gallons. In second and third brood control experiments, however, the minimum effective concentration appeared to be somewhere above 4 ounces. There was also increased control with repeated applications. Parathion seemed readily compatible with all other materials tested and there was no evidence of injury to fruit, foliage or cover crop.

ARSENATE OF LEAD AND DDT.—Arsenate of lead is very toxic to red-banded leaf roller larvae but it did not give satisfactory control of first brood larvae. It was much more effective in the control of second and third brood larvae than for the first brood larvae. Leaf roller larvae prefer and select new succulent tender foliage on which to feed. This type of foliage is usually most abundant on vigorous water sprouts. In the early season this type of growth is so rapid that it is very difficult to keep it well protected with a toxic spray such as arsenate of lead. Within a day or so after a spray application sufficient new foliage growth has taken place to afford opportunity for the larvae to find ample unsprayed foliage on which to feed. Later in the season when the rate of growth is slower it is less difficult to keep the foliage well covered with a protective coating of poison with the results that such materials as arsenate of lead and DDT are much more effective in the control of second and third brood larvae than they are for first brood larvae. The standard recommended arsenate of lead-DDT schedule consisted of 3 pounds of arsenate of lead in the petal-fall and first and second cover sprays and 2 pounds of DDT, 50 per cent wettable powder, in the second to the fifth cover sprays inclusively. First brood counts following the second cover spray showed 86 larvae and pupae for the five trees. This count had only increased to 111 by the end of the second brood with an infestation at harvest of 16.4 per cent.

DDT is also fairly toxic but results indicate that the minimum effective concentration lies between 3 and 4 pounds toxicant per 100 gallons.

SUMMARY AND CONCLUSIONS.—Liquid dichlorodiphenyl dichloroethane is the most effective material tested in the experiments herein reported for the control of the red-banded leaf roller larvae. The minimum effective concentration is near 8 ounces of toxicant per 100 gallons of diluted spray. The liquid form is much more effective than the wettable powder form. It is compatible with most standard insecticides, acaricides and fungicides with the exception of DN-111. It is safe to use on fruit and foliage. The proper

use of this material will eliminate all danger of leaf roller damage.

A chlorinated camphene[1] is another new material which shows a very high degree of toxicity to red-banded leaf roller larvae. At a concentration of one pound per 100 gallons it was very effective. It gave control equal to parathion and comparable to that afforded by rhothane. It was not injurious to fruit or foliage.

Parathion is extremely effective in the control of the red-banded leaf roller larvae. It is equal to dichlorodiphenyl dichloroethane in toxicity but is not equal in effectiveness because it does not have the penetrating and contact toxicity of the latter. It is very toxic at concentrations as low as 1 ounce per 100 gallons but results indicate that the minimum effective concentration is near 4 ounces per 100 gallons. Parathion is compatible with most insecticides, fungicides and acaricides and results to date indicate that it is not injurious to fruit, foliage or cover crop.

Arsenate of lead and DDT are toxic to leaf roller larvae but are not equal to dichlorodiphenyl dichloroethane, toxaphene or parathion in the control of first brood. They are more effective against second and third broods but are still not satisfactory.

[1] *Toxaphene.*

Certain Compounds Containing the Methylenedioxyphenyl Group as Synergists for Pyrethrum to Control Flies and Mosquitoes[1]

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During 1944 and 1945 a rather extensive program of screening tests was in progress to discover new insecticides and materials which might serve as synergists in combination with known insecticides. Eagleson (1940) showed that sesame oil increased the effectiveness of pyrethrum, and Haller *et al.* (1942) showed that this material owed its synergistic property to the presence of sesamin. Other investigators have shown that a number of compounds containing the methylenedioxyphenyl group act as synergists for pyrethrum (Harvill *et al.* 1943, Gertler *et al.* 1943, Gersdorff & Gertler 1944, Synerholm *et al.* 1945). The writers have found that piperonyl cyclonene (Wachs 1947) increases the toxicity of pyrethrum in various forms.[4] Other substances containing the methylenedioxyphenyl group have been tested by the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine, and the results obtained with 30 of these compounds are reported herein. The tests for the most part are preliminary in nature, and intensive study of individual compounds will give a truer picture of their relative value as synergists for pyrethrum.

SMALL-SCALE SCREENING TESTS.—The tests were made in 100-cubic foot chambers. After the materials had been atomized in the chamber, house flies, *Musca domestica* L., and mosquitoes, *Anopheles quadrimaculatus* Say or *Aëdes aegypti* (L.), in small screen cylinders (2.75 by 7 inches) were exposed by swinging the cylinders on a pendulum in the chamber. After the mosquitoes had been exposed for 10 seconds and the flies for 30 seconds, they were removed from the chamber and transferred to clean cages. The numbers of insects knocked down were recorded after 10 and 30 minutes. Food and water were then supplied to the insects, and the mortality was recorded the following day. Duplicate cages were used and each test was repeated; therefore, the result of one replication is an average of four cages for each species.

Ten per cent of the test material was added to a standard formula consisting of 1 per cent of DDT and 0.1 per cent of pyrethrins in cyclohexanone. It was believed that significant increases in knockdown and mortality over those obtained

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[2] Now with U. S. Industrial Chemicals, Inc.
[3] Acknowledgement is given for the work of John E. Williams, Corporal, AUS, assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides at Army Air Forces Center, Orlando, Fla.
[4] Unpublished data.

with the standard formula alone would occur if the test material held promise as an insecticide in itself or as a synergist for either pyrethrum or DDT, and that promising materials could then be evaluated further by more sensitive tests. This was done in some cases by reducing the amount of the test material added to the standard formula from 10 per cent to 5 per cent and 1 per cent, and by testing it alone and in combination with only one of the two known insecticidal ingredients.

The results obtained in these tests are reported in table 1. This table also includes the results obtained in the tests with the more promising materials in the group, in which reduced amounts of the compound were added to the standard solution. At a concentration of 10 per cent, nine materials gave a great increase in knock-down of house flies over that obtained with the standard formula. Four failed to give a distinct increase in fly mortality. Of the six compounds tested at a concentration of 5 per cent, four were much more effective than the standard formula. When tested at a 1 per cent concentration, the same four were still distinctly more effective than the control and five others showed a definite increase in mortality. The materials most effective against flies were piperonyl cyclonene; 4-(3,4-methylene-dioxyphenyl)-5-methyl-1-1, 3-dioxane; 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane; sesamin concentrate; and piperonylic acid, *n*-amyl ester.

Against mosquitoes, all the compounds increased the knockdown at 30 minutes by about 100 per cent over that obtained with the standard formula. In most cases the knock-down was almost complete. There was a greater variation in the mortality obtained. Most of the compounds tested at concentrations of 5 and 1 per cent continued to give significant increases in knockdown as well as in mortality. The materials which appeared to be most effective against mosquitoes were 4-(3,4-methylene-dioxyphenyl)-5-methyl-1,3-dioxane; 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane; piperonylic acid, *n*-propyl ester; piperonylic acid, *n*-butyl ester; piperonylic acid, *n*-amyl ester; piperonylidenemalonic acid, di-*n*-butyl ester; 1-(3,4-methylenedioxyphenyl)-1-acetoxybutene-3; and sesamin concentrate.

SEMI-PRACTICAL TESTS.—Some of the more promising compounds were also tested in large rooms (7000 cu. ft.) in semi-practical tests. The spray was discharged from an atomizer and thoroughly dispersed in the room by operating a 16-inch electric fan for 1 minute after discharge of the spray. House flies and *Anopheles quadrimaculatus* mosquitoes were then exposed in small screen cages by carrying them about in the room, the house flies for 5 minutes and the mosquitoes for 1 minute. After exposure they were immediately transferred to clean holding cages, and records were taken of knockdown in 10 minutes, 30 minutes, and 2 hours. The mortality was recorded after 24 hours. Food and water were also supplied to these insects after the knockdown records had been completed.

The effectiveness of three synergists was compared in a concentrated spray formula (without DDT) consisting of 2 per cent of pyrethrins, 20 per cent of an aromatic petroleum fraction[1] and 20 per cent of the synergist, using kerosene as the diluent. Benzene was used as the diluent in the solution containing sesamin concentrate. A practical concentrated spray formula containing DDT and pyrethrum, and a formula containing no synergist or DDT were also included for comparison. Different dosages were used for flies and mosquites.

The results of these tests are given in table 2. At the dosage of 10 mg. of pyrethrins for flies and 1.21 mg. for mosquitoes the formula containing no synergist or DDT gave a good initial knock-kown of flies but permitted almost complete recovery, the mortality being only 7 per cent. All the formulas containing synergists gave a complete and sustained knockdown of flies and a highly significant increase in mortality over the spray containing no synergist or DDT. The formula containing DDT but no synergist gave slightly less knockdown of flies than the formulas containing synergists but no DDT. Against mosquitoes there was less difference between treatments, but the synergists greatly increased the knockdown as well as the mortality. The one most effective against both species was 4-(3,4-methylenedioxyphenyl)-5-methyl-1,3-dioxane.

[1] APS-202.

Table 1.—Effect on house flies and mosquitoes of various amounts of compounds containing the methylened ioxyphenyl group when added to a standard formula containing 0.1 per cent of pyrethrins and 1 per cent DDT in cyclohexanone. Dosage per 1000 cubic feet: 7.5 mg. of pyrethrins: 75 mg. of DDT.

Compound	Replications	House Flies			Mosquitoes		
		Knockdown in Minutes		Mortality in 24 Hours	Knockdown in Minutes		Mortality in 24 Hours
		10	30		10	30	
				Per Cent			
Standard formula (pyrethrins 0.1% + DDT 1% in cyclohexanone	17	1	2	48	23	45	47
Sprays containing 10 per cent synergist							
Butyl safrole $(CH_2O_2)(C_4H_9)C_6H_2CH_2CH{:}CH_2$	2	2	5	62	32	96	79
Piperonal glycerol acetal $CH_2O_2C_6H_3CHOCH(O)CH_2OH$	3	1	2	78	32	93	89
4-(3,4-Methylenepioxyphenyl)-5-methyl-1, 3-dioxane $CH_2O_2C_6H_3CHCH(CH_3)CH_2OCH_2O$	3	55	60	77	64	93	99
2 (3,4 Methylenedioxyphenyl)-4,4-diethyl-1,3 -dioxane $CH_2O_2C_6H_3CHOC(C_2H_5)_2CH_2CH_2O$	2	48	42	76	63	99	100
Piperonyl cyclonene $CH_2O_2C_6H_3CHCH_2C(C_5H_{11}){:}CHCOCHCOC_2H_5$ $+CH_2O_2C_6H_3CHCH_2C(C_5H_{11}){:}CHCOCH_3$	4	66	88	65	43	89	97
Piperonylic acid, ethyl ester $CH_2O_2C_6H_3COOC_2H_5$	1	2	0	71	49	91	72
Piperonylic acid, *n*-propyl ester $CH_2O_2C_6H_3COOC_3H_7$	2	26	5	68	68	98	91
Piperonylic acid, *n*-butyl ester $CH_2O_2C_6H_3COOC_4H_9$	2	40	9	76	65	98	97
Piperonylic acid, *n*-amyl ester $CH_2O_2C_6H_3COOC_5H_{11}$	2	46	23	80	80	99	93
Piperonylic acid, tetrahydrofurfuryl ester $CH_2O_2C_6H_3COOCH_2C_4H_7O$	2	30	41	64	45	95	87
3,4-Methylenedioxycinnamic acid, ethyl ester $CH_2O_2C_6H_3CH{:}CHCOOC_2H_5$	1	5	6	74	55	99	1000
Piperonylmalonic acid, diethyl ester $CH_2O_2C_6H_3CH_2CH(COOC_2H_5)_2$	1	2	6	66	21	96	46
Piperonylidenemalonic acid, diethyl ester $CH_2O_2C_6H_3CH{:}C(COOC_2H_5)_2$	1	0	4	70	33	94	79
Piperonylidenemalonic acid, di-*n*-butyl ester $CH_2O_2C_6H_3CH{:}C(COOC_4H_9)_2$	1	0	1	71	27	96	97
Acetic acid, piperonyl ester $CH_3COOCH_2C_6H_3O_2CH_2$	1	0	0	9	34	91	52
1-(3,4-Methylenedioxyphenyl)-1-acetoxybutene-3 $CH_3COOCH(C_6H_3O_2CH_2)CH_2CH{:}CH_2$	1	4	3	14	93	99	78
Propionic acid, piperonyl ester $CH_3CH_2{\cdot}COOCH_2C_6H_3O_2CH_2$	1	0	1	23	85	99	70
Butyric acid, piperonyl ester $CH_3CH_2CH_2COOCH_2C_6H_3O_2CH_2$	1	0	0	23	86	97	68
Piperonyl acetonitrile $CH_2O_2C_6H_3CH_2CH_2CN$	2	3	9	89	39	95	85
N,N-Diethylpiperonylamide $CH_2O_2C_6H_3CON(C_2H_5)_2$	2	66	71	80	76	97	99
Sesamin concentrate	1	34	81	72	41	99	98
Sprays containing 5 per cent of synergist							
Butyl safrole	1	0	0	52	37	89	61
Piperonal glycero, acetal	1	0	0	56	64	97	94
4-(3,4-Methylenedioxyphenyl)-5-methyl-1,3-dioxane	4	23	21	71	54	96	98
2-(3,4-Methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane	2	35	41	76	41	98	98
Piperonyl cyclonene	4	37	51	56	41	74	77
Sesamin concentrate	4	48	36	48	47	78	87
Sprays containing 1 per cent of synergist							
Piperonal glycerol acetal	1	1	1	71	42	59	69
4-(3,4-Methylenedioxyphenol)-5-methyl-1,3-dioxane	1	14	15	79	29	72	80
2-(3,4-Methylenedioxyphenol)-4,4-diethyl-1,3-dioxane	1	9	9	64	18	80	41
Piperonyl cyclonene	1	9	37	70	14	54	53
Piperonylic acid, *n*-propyl ester	1	1	1	62	23	76	44
Piperonylic acid, *n*-buty, ester	2	5	2	74	36	91	64
Piperonylic acid, *n*-amyl ester	2	1	0	52	40	93	79
3,4-Methylenedioxycinnamic acid, ethyl ester	2	7	7	45	36	96	78
Piperonylidenemalonic acid, *n*-butyl ester	2	3	0	60	60	96	93
Piperonyl acetonitrile	2	1	1	69	37	72	55
Sesamin concentrate	1	25	24	57	26	87	84

One additional compound, 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane, was included when the synergists were compared at a lower dosage. The dosage of pyrethrins was reduced to 5 mg. per 1000 cu. ft. for flies to give a better comparison of the knock-down properties of the four activators.

Table 2.—Comparative effectiveness of spray formulas, with and without synergists of the methylenedioxyphenyl group, when applied in semi-practical tests against houseflies and mosquitoes. Average of three tests.

Formulas	Houseflies: Knockdown in Minutes 10	30	120	Houseflies: Mortality in 24 Hours	Mosquitoes: Knockdown in Minutes 10	30	120	Mosquitoes: Mortality in 24 Hours
	Per cent			*Per cent*	*Per Cent*			*Per cent*
Dosage of pyrethrins per 1000 cubic feet: 10 mg. for flies (70 per test); for mosquitoes 1.21 mg. (140 per test)								
Pyrethrins 2%+APF[1] 20% in cyclohexanone (no synergist or DDT)	86	47	1	7	41	87	65	50
Pyrethrins 2%+APF 20%+ synergist 20%:								
4-(3,4-Methylenedioxyphenyl)-5-methyl-1,3-dioxane	100	100	100	76	77	97	100	97
Piperonyl cyclonene	100	100	100	60	76	93	97	90
Sesamin concentrate	100	100	99.7	33	65	92	94	89
Pyrethrins 2%, APF[1] 40%, DDT 20% (no synergist)	90	100	99.5	99	51	81	92	77
Dosage of pyrethrins per 1000 cu. ft.: 5 mg. for flies (50 per test); 2 mg. for mosquitoes (90 per test)								
Pyrethrins 2%, APF 20% in cyclohexanone (no synergist)	38	11	1	2	37	51	75	44
Pyrethrins 2%+APF 20%+ synergist 20%:								
4-(3,4-Methylenedioxyphenyl)-5-methyl-1,3-dioxane	91	88	2	6	59	75	94	75
Piperonyl cyclonene	91	98	51	12	45	66	98	81
2-(3,4-Methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane	79	45	8	2	82	100	100	100
Sesamin concentrate	94	96	25	6	70	92	96	91
Pyrethrins 2%, APF 40%, DDT 20% (no synergist)	41	42	53	93	60	87	91	80

[1] Aromatic petroleum fraction.

Table 3.—Comparative effectiveness of spray formulas, with and without synergists but all containing DDT, when applied in semipractical tests against house flies and mosquitoes. Average of 3 tests. About 60 houseflies and 80 mosquitoes used in each test. Dosages per 1,000 cu. ft.: 5 mg. of pyrethrins and 50 mg. of DDT for flies: 2 mg. of pyrethrins and 10 mg. of DDT for mosquitoes.

Formula	House Flies: Per Cent Knockdown in Minutes 10	30	120	House Flies: Per Cent Mortality 24 Hours	Mosquitoes: Per Cent Knockdown in Minutes 10	30	120	Mosquitoes: Per Cent Mortality 24 Hours
Pyrethrins 20%+DDT 10%+APF-202 20% in cyclohexanone (no synergist)	28	29	45	70	45	50	68	80
Pyrethrins 2%+DDT 10%+APF-202 20%+synergist 20%:								
4-(3,4-Methylenedioxyphenyl)-5-methyl-1,3-dioxane	80	89	46	62	71	91	97	96
Piperonyl cyclonene	90	99	77	68	51	78	95	91
2-(3,4-Methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane	87	89	48	69	66	98	99	94
Sesamin concentrate	95	98	70	79	53	94	97	97
Pyrethrins 2%+DDT 20%+APF-222 40% (no synergist)[1]	39	62	58	93	64	98	96	85

[1] Dosage of DDT per 1,000 cu. ft.: flies 50 mg., mosquitoes 20 mg.

Sesamin concentrate and piperonyl cyclonene gave the best knock-down, the latter showing the greater tendency to sustain the knock-down. 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane was the least effective against flies. The formula containing DDT but no synergist gave high mortality (93 per cent) of flies, but the knock-down was less than it was with the formulas containing synergists but no DDT.

Against mosquitoes 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane gave by far the best results, with a high initial knock-down and complete mortality. Sesamin concentrate was somewhat more effective than either of the remaining two activators. The spray containing DDT gave results about as good as those obtained with the less effective synergists.

The four synergists were tested further in pyrethrum sprays containing 10 per cent of DDT. The results are given in table 3. Against flies the addition of 10 per cent of DDT did not increase the initial knock-down but did help to sustain the knock-down and, in some cases, to increase the mortality. Of the synergists sesamin concentrate gave the best results. Due to the limited number of tests the smaller differences may not be significant. The formulas containing 20 per cent of DDT but no synergist gave a higher mortality than the formulas containing 20 per cent of synergist and 10 per cent of DDT. There was little difference in the effect of the synergists against mosquitoes except that 4-(3,4-methylenedioxyphenyl) -5-methyl-1,3-dioxane gave the greatest initial knock-down.

A number of compounds containing the methylene-dioxyphenyl group, in addition to those listed in the tables, were also tested. The substances which showed no material increase in knock-down or mortality of either house flies or mosquitoes in one replication were as follows: Piperonal; piperine; isosafrole; dihydrosafrole; N-(3,4 methylene dioxythiobenzoyl) morphaline; N-(3,4-methylenedioxythiobenzoyl) piperidine; 3,4-methylenedioxy-beta-nitrostyrene; and propionic acid, 2,3-methylenedioxypropyl ester.

SUMMARY.—Thirty compounds containing the methylenedioxyphenyl group were tested as synergists for pyrethrum. The tests were made in small chambers (100 cu. ft.) and also in large rooms (7000 cu. ft.). The materials were tested first at a 10 per cent concentration in a formula containing 1 per cent of DDT and 0.1 per cent of pyrethrins in cyclohexanone. The more effective compounds were also tested at concentrations of 5 per cent and 1 per cent. Solutions containing 2 per cent of pyrethrins and 20 per cent of the synergists were used in the room tests. At the 10 per cent concentration 20 compounds greatly increased the knockdown and mortality of *Anopheles quadrimaculatus* Say. Only about half as many compounds were effective against house flies, *Musca domestica* L. The effect on house flies was greater in knockdown than in mortality. Ten of the compounds tested had no significant effect on either test insect. Materials effective against both flies and mosquitoes were piperonyl cyclonene; 4-(3,4-methylenedioxyphenyl)-5-ethyl-1,-3-dioxane; 2-(3,4-methylenedioxyphenyl)-4,4-diethyl-1,3-dioxane; sesamin concentrate; and piperonylic acid, *n*-amyl ester. Additional compounds especially effective against mosquitoes were a number of other esters of piperonylic acid, the di-*n*-butyl ester of piperonylidenemalonic acid, and 1-(3,4-methylenedioxyphenyl)-1-acetoxybutene-3.

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Inhibition of the Field Decomposition of DDT Spray Deposits on Citrus[1]; Preliminary Results

F. A. GUNTHER,[2] G. E. CARMAN,[3] and M. I. ELLIOT[4]

In 1946 the results of a brief study designed to demonstrate the persistence of certain typical DDT spray deposits on citrus were published (Gunther *et al.* 1946). Each of the 12 different treatments involved showed a loss after 86 days in the field of from 71 to 95 per cent of the original quantity of DDT deposited, as demonstrated both by chemical assay (Gunther 1948) and by decreasing insecticidal efficiency of the considerable white crystalline deposits on leaves and fruit in preventing development of the young crawlers of the California red scale, *Aonidiella aurantii* (Mask.) (Lindgren & Boyce 1944, Lindgren *et al.* 1944).

Microscopic examination of this heavy less toxic crystalline residue revealed that it was composed of a mat of fine needles, platelets, and shards partially embedded in the leaf and fruit waxes, along with considerable dust and detritus of the sorts commonly found on plant surfaces grown in arid regions. In order to obtain enough of this comparatively non-toxic residue for chemical examination, mature navel orange trees were sprayed thoroughly, eight with three pounds of technical DDT dissolved in nine per cent kerosene emulsion, and eight with four pounds of a 75 per cent wettable concentrate of DDT per 100 gallons. Periodic chemical estimations of DDT residues indicated that after 130 days only 4 to 5 per cent of the initial deposits remained, whereas much crystalline material was visibly apparent on the leaf surfaces. From 100,000 of these leaves there was obtained, by appropriate methods, 39.4 grams of a white, semicrystalline sludge freed from plant waxes. The application of chromatographic and other techniques[5] resulted in the isolation and identification of the compounds shown in figure 1. The degradation routes indicated therein are not definitely established, but rather constitute a rational approach toward an explanation of the origin of the various decomposition products isolated in assayable amounts. Several other, less well-defined product have also been isolated. Pending the final outcome of work currently in progress, it appears that all structures tentatively assigned to these other products can also be related indirectly to the p,p′-DDT ethylene rather than to the parent p,p′-DDT molecule itself.

These studies indicated, therefore, that under our field conditions any DDT undergoing alteration *in situ* was decomposed by way of the ethylenic derivative. The techniques available to us did not permit sufficiently precise quantitative measurements to enable the estimation of the quantity of DDT that might have been displaced as such from the plant tissues, although the combined yields of decomposition products would seem to indicate that the quantity in question was not large.

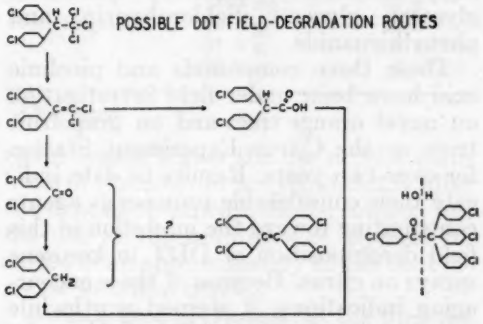

FIG. 1.—Suggested degradation routes for the major part of the field decomposition of DDT under the conditions described in the text.

Thus, it appeared that dehydrohalogenation was the key reaction in the field decomposition of the DDT. Further, it seemed reasonable that inhibition of this dehydrohalogenation process would result in increased field stability, a desirable goal in some instances for practical field control of specific insect pests.

The preliminary results of a laboratory investigation designed to evaluate this possibility were published in 1946 (Gun-

[1] Presented in part before the Pacific Slopes Branch meeting of the American Association of Economic Entomologists in Vancouver, B. C., June 15, 1948.

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[5] Full details of isolation and elucidation of structure will be reported elsewhere. Manuscript in preparation.

ther & Tow 1946), and the more detailed description was published in 1947 (Gunther & Tow 1947). As is well known, the dehydrohalogenation of DDT may be catalyzed by traces of numerous substances, *e.g.*, iron or some of its salts, with the rate of dehydrohalogenation dependent in large part upon temperature of environment. The laboratory studies reported in the two publications cited indicated that picolinic acid in particular would very effectively inhibit the iron-catalyzed thermal decomposition of technical grade DDT at concentrations as low as 2 per cent of the inhibitor. Picolinic acid, however, is at present unavailable commercially except in small quantities. Continuation of the laboratory investigations along the lines already reported resulted in the finding of three other seemingly satisfactory inhibitory materials; glycerol, glycerol dichlorohydrin, and phenylbiguanide.

These three compounds and picolinic acid have been under field investigation on navel orange trees and on grapefruit trees at the Citrus Experiment Station for over two years. Results to date indicate their considerable promise as agents contributing toward the inhibition of this field decomposition of DDT in kerosene sprays on citrus. Because of these encouraging indications, it seemed worthwhile to report certain aspects of the field results available to date with the thought that perhaps they would stimulate other investigators to examine the potential utility of these candidate inhibitors under a variety of conditions and as constituents of other formulations of DDT.

MATERIALS AND METHODS.—Picolinic acid is available in small quantities through Eastman Kodak Company as the hydrochloride or through laboratory synthesis (*e.g.*, Singer & McElvain 1940) as the hydrochloride. Glycerol C. P.—U. S. P. is available from a number of sources; the glycerol dichlorohydrin and the phenylbiguanide were obtained through the courtesy of the Shell Chemical Company and the American Cyanamid Company, respectively. The DDT used was technical grade material, with a minimum setting point of 89° C. Horticultural grade kerosene was employed in all spray mixtures; this kerosene distills not more than 5 per cent at 365° F. and not less than 98 per cent at 540° F., and has an unsulfonated residue of not less than 92 per cent.

Mature navel orange and grapefruit trees were sprayed in the conventional manner and with conventional high-pressure equipment at the approximate rate of 20 gallons of finished spray per tree. In all instances, the quantities of inhibiting agents specified in subsequent discussions and tables were tank mixed with 3 gallons of kerosene, 2 pounds of technical grade DDT, and 4 ounces of blood albumin spreader. After all the DDT had been forced into solution in the kerosene,[6] and the solution emulsified in a small amount of water with the aid of blood albumin, the final volume was adjusted to 100 gallons with water.

Table 1.—Amounts of various candidate inhibitors of the field decomposition of DDT applied to two varieties of citrus.

CANDIDATE INHIBITOR	QUANTITY ADDED TO SPRAY MIXTURE[1]	
	Grape fruit	Navel oranges
Glycerol	—	37.5 ml.
Glycerol	375 ml.	—
Glycerol	750 ml.	750 ml.
Glycerol	1500 ml.	—
Glycerol dichlorohydrin	—	45.5 g.
Glycerol trichlorohydrin	—	45.5 g.
Phenylbiguanide	45.5 g.	45.5 g.
Phenylbiguanide	91.0 g.	—
Phenylbiguanide	182.0 g.	—
Phenylbiguanide · HCl[2]	54.8 g.	54.8 g.
Picolinic Acid · HCl[2]	—	59.0 g.
o-Tolylbiguanide	45.5 g.	45.5 g.
Phenylbiguanide salt of 2-Mercaptobenzothiazole	45.5 g.	45.5 g.

[1] Two pounds of technical DDT dissolved in three gallons of kerosene per one hundred gallons of finished spray.
[2] Plus the theoretical amount of potassium carbonate to liberate the free base.

Representative duplicate samples of 125 leaves each were collected at suitable intervals and in a carefully prescribed manner (Gunther 1948) from each plot of sprayed trees. Within 24–48 hours, the total leaf area per sample was obtained by photoelectric means, and the total DDT was quantitatively removed from the leaf surfaces with 250 milliliters of benzene per sample with the aid of a drum-type stripping machine. Subsequent quantitative estimation of the DDT was made by the dehydrohalogenation pro-

[6] Solution of the DDT in the kerosene is readily achieved by circulating the mixture through the pump 2 to 3 minutes and by maintaining adequate agitation within the tank. Frictional heat is a contributing factor.

cedure (Gunther 1948). All analytical values represent the average of at least two replicate samples.

The various candidate inhibitors are shown in table 1. In general, both laboratory and limited field experiences aided in the selection of these particular compounds as being worthy of further study. The quantities of inhibitors, however, were chosen so as to represent reasonable and practicable ranges in concentration for the two most promising materials. The minimum quantities for all the compounds represent 5 per cent of the weight of the DDT present since previous laboratory studies (Gunther & Tow 1946) had indicated that the optimum concentration of inhibitor (picolinic acid) appeared to lie between 2 and 20 per cent. All hydrochlorides were increased in stoichiometrical amounts so as to afford the same weights of free bases for more cogent comparisons with the other candidate inhibitors.

RESULTS AND DISCUSSION.—At the concentrations used and under the conditions described, some of the candidate inhibitors exhibited pronounced deposit-building properties, whereas others decreased the initial deposits. Typical initial deposits illustrating these variations are shown in table 2. These data demonstrate

Table 2.—The effects of some of the candidate inhibitors upon magnitudes of initial deposits of DDT.

CANDIDATE INHIBITOR	QUANTITY USED	INITIAL DEPOSIT OF DDT, MG.[1]/CM.[2]	
		Grapefruit Leaves	Navel orange Leaves
Control	—	16.2	20.1
Glycerol	750 ml.	11.2	24.4
Phenylbiguanide	45.5 g.	10.9	37.7
Phenylbiguanide · HCl[3]	54.8 g.	12.3	19.7
o-Tolybiguanide	45.5 g.	15.4	35.0
Picolinic Acid · HCl[3]	59.0 g.	—	16.5

[1] Micrograms.
[2] Plus the theoretical amount of potassium carbonate to liberate the free base.

clearly that a lighter deposit of DDT was obtained on grapefruit leaves than on navel orange leaves, and that the materials that increased the deposit of DDT on the orange leaves actually decreased the deposit on the grapefruit leaves. It is also noteworthy that on the orange leaves the addition of phenylbiguanide to the spray mixture nearly doubled the initial deposit; whereas the use of phenylbiguanide HCl neutralized with potassium carbonate did not seem to affect the initial deposit appreciably.

Since difficulty is encountered in obtaining a high deposit of DDT on the surfaces of grapefruit leaves, the effects of varying amounts of glycerol and of phenylbiguanide were evaluated. The initial deposits resulting therefrom are shown in table 3. By way of contrast, on

Table 3.—Initial deposits of DDT resulting from the applications of sprays containing empirical ranges of concentrations of two candidate inhibitors on grapefruit leaves.

CANDIDATE INHIBITOR	QUANTITY USED	INITIAL DEPOSIT OF DDT MG.[1]/CM.[2]
Control	—	16.2
Glycerol	375 ml.	13.7
	750 ml.	11.2
	1500 ml.	10.2
Phenylbiguanide	45.5 g.	10.9
	91.0 g.	8.9
	182.0 g.	6.9

[1] Micrograms.

navel orange leaves the use of 37.5 milliliters of glycerol did not significantly alter the deposit obtained with the control, but the use of 750 milliliters of glycerol resulted in an approximately 25 per cent increase in initial deposit.

As indicated previously, at the time the particular series of experiments under consideration was planned, the four most promising candidate inhibitors were glycerol, phenylbiguanide, glycerol dichlorohydrin, and picolinic acid. In figure 2 are

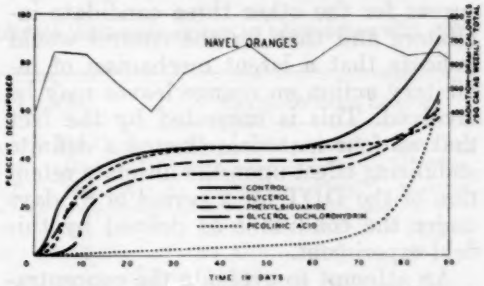

FIG. 2.—Time-inhibition curves for four of the most promising candidate inhibitors of DDT decomposition on navel orange leaves.

shown the fitted curves resulting from the field studies with these four materials to determine their effects on the persistence of DDT deposits. As ordinate, "per cent decomposed" (DDT) was selected so as to

eliminate for purposes of this comparison the variations in initial DDT deposits. Thus, all curves have a common origin at zero per cent decomposed; the curve terminals, then, represent direct measures of inhibitory potential after 87 days,[7] while the curves themselves permit direct analyses and comparisons of inhibitor behavior.

In order to facilitate evaluations of this last parameter, the total incident solar radiation during the course of the experiment has been plotted on the same graph in figure 2 (and in all succeeding figures). The magnitude and extent of this radiation were determined with an *Eppley* pyroheliometer, but for purposes of clarity the time-radiation values are depicted as weekly totals based upon gram-calories per square centimeter of horizontal surface.

Even though fitted, the decomposition curves of DDT when used with three of these materials demonstrate a rough correlation with the thermal input. The behavior of the picolinic acid is at marked variance to the general pattern, however, possibly indicating that thermal decomposition of this inhibitor, with resultant loss of inhibitory powers, is not so much of a factor as, perhaps, mere volatility (or absorption). Thus, it would seem that a catalytic amount of picolinic acid suffices for inhibition; slow removal of the excess quantity through some unknown agency resulted in eventual decrease below the optimum catalytic quantity with resultant accelerated decomposition of the DDT. The close resemblance between the curves for the other three candidate inhibitors and that for the control would indicate that a latent mechanism of inhibitory action on orange leaves may be involved. This is suggested by the fact that all four materials exerted a definite stabilizing effect upon the ultimate retention of the DDT for a period of 87 days under the conditions as defined by this field experiment.

An attempt to evaluate the concentration effect of glycerol as an inhibitor of DDT decomposition on navel orange leaves is similarly demonstrated graphically in figure 3. Possible interpretation of these curves would be that the higher

[7] The field decomposition studies reported previously (Gunther *et al.* 1946) indicated the rates of decomposition (or disappearance) of DDT to be independent of magnitudes of initial deposits, under the conditions specified.

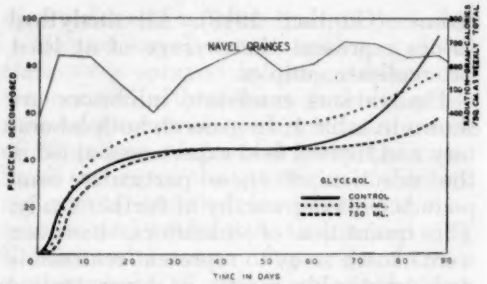

FIG. 3.—Time-inhibition curves illustrating the role of concentration of glycerol in inhibiting the field decomposition of DDT on navel orange leaves.

concentration of glycerol exhibited some inhibitory properties after approximately 65 days in this experiment. Further, it appears that the use of the lower concentration actually resulted in an increased rate of decomposition of the DDT initially, but that the prolonged hot spell during the last 40 days increased the rate of decomposition of the control more than those for both concentrations of glycerol.

The concentration effect of phenylbiguanide as an inhibitor of DDT decomposition is represented graphically in figure 4 with three concentrations applied

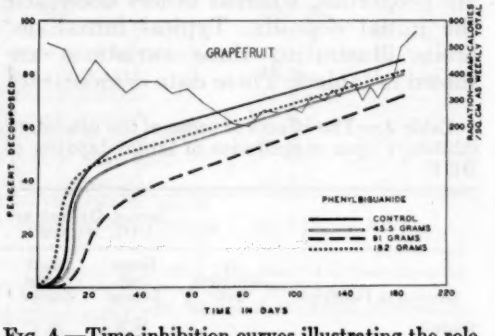

FIG. 4.—Time-inhibition curves illustrating the role of concentration of phenylbiguanide in inhibiting the field decomposition of DDT on grapefruit leaves.

to grapefruit leaves. It is even more apparent from these curves that the rate of field decomposition of DDT on these leaves is a function of thermal input (*i.e.*, high leaf temperatures). That the phenylbiguanide may be functioning inefficiently in a truly inhibitory manner is suggested. In this test, 91 grams of the compound per 100 gallons of final aqueous spray mixture containing 3 gallons of kerosene, 2 pounds of DDT, and 4 ounces of blood albumin spreader proved to be the most effective concentration. The similar shapes of all four curves would seem to indicate again

that possibly the phenylbiguanide slowly loses any DDT-decomposition inhibiting powers it may have through its own secondary decomposition or displacement.

A more elaborate evaluation of the role of concentration in the inhibitory influence of glycerol is shown in figure 5.

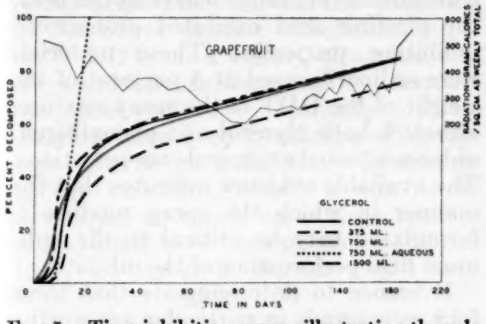

FIG. 5.—Time-inhibition curves illustrating the role of concentration of glycerol in inhibiting the field decomposition of DDT on grapefruit leaves.

Three concentrations of glycerol were added to the previously indicated quantities of kerosene, DDT, and blood albumin spreader, then tank mixed as usual to effect solution and then diluted with water to the final volume of 100 gallons and applied to grapefruit trees.

A fourth mixture was prepared wherein the glycerol was not added until final volume had been reached. The dotted line in figure 5 ("750 ml. aqueous") represents the fate of the DDT in this spray mixture: the DDT had quantitatively decomposed after 20 days in the field, as contrasted with approximately 85 per cent decomposition of the control after 187 days in the field. These data strikingly illustrate the possible importance of the order of mixing such inhibitory materials.

Again the behavior of the other four curves indicates parallelism between uninhibited DDT decomposition, glycerol inhibited DDT decomposition, and thermal input. Other field experiments involving quantities of glycerol in excess of 1500 milliliters (up to 3000 milliliters per 100 gallons) indicate that the optimum concentration of glycerol on grapefruit leaves is approximately 2000 milliliters per 100 gallons of spray mixture.

The data pertinent to figures 4 and 5 represent field experiments lasting 187 days, whereas those portrayed graphically in figures 2 and 3 represent durations of only 87 days in the field. It should be pointed out, however, that sustained periods of high thermal input (*i.e.*, high leaf temperatures) were more predominant in the experiments with the navel oranges as portrayed in figures 2 and 3; in these experiments, also, the maximum sustained weekly total incident radiation approached 700 gram-calories per square centimeter of horizontal surface whereas the maximum attained in the grapefruit experiments was well under 600 gram-calories per square centimeter.

For purposes of direct comparison, the initial deposits, the final deposits, and the resultant per cent decomposition of the DDT in admixtures with several candidate inhibitors have been collated in table 4. These data may be considered representative of those being obtained in repeated experiments, but it must be

Table 4.—Relative efficiencies of the various candidate inhibitory agents in admixtures with DDT in the standardized formulation.

Candidate Inhibitor	Quantity Used	Grapefruit Leaves			Navel Orange Leaves		
		Deposit Mg.[1]/cm.[2]		Per Cent Decomposition	Deposit Mg.[1]/cm.[2]		Per Cent Decomposition
		Initial	Final[2]		Initial	Final[3]	
Control	—	16.2	2.2	86.4	20.1	1.7	91.5
Glycerol	750 ml.	11.2	1.6	85.7	24.4	10.2	58.2
Glycerol Dichlorohydrin	45.5 g.	—	—	—	15.3	4.9	68.0
Glycerol Trichlorohydrin	45.5 g.	—	—	—	17.4	2.0	88.5
Phenylbiguanide	45.5 g.	10.9	2.2	79.8	37.7	15.0	60.2
	91.0 g.	8.9	2.5	71.9	—	—	—
	182.0 g.	6.9	1.4	79.7	—	—	—
Picolinic Acid · HCl	59.0 g.	—	—	—	16.5	10.2	64.2

[1] Micrograms.
[2] After 187 days.
[3] After 87 days.

emphasized that our typical quantitative data can be compared only within experiments performed simultaneously and on the same variety of citrus. Data from other experiments both completed and in progress indicate trends that are in general similar to those presented. The data in the present report, however, demonstrate clearly that the environmental influence upon the behavior of these DDT-decomposition inhibitors is so pronounced as to preclude any attempts at prediction of behavior under conditions other than those specified herein.

Consequently, this report is presented in the hope that it will stimulate similar investigations by other workers and under other environmental conditions. There are so many unknown factors and unsolved relationships involved in this obviously promising phase of the use of DDT as an insecticide that the results reported herein can be considered introductory only. For example, extended concentration ranges, other climatic conditions and other varieties of plants, the possibilities of employing inhibitors supplemented with deposit-building agents, etc., are currently being investigated.

Precise explanations relative to the mechanisms whereby these candidate inhibitors exert their varied effects are not apparent at this time, although the picolinic acid does appear to be truly anti-catalytic in its action.

SUMMARY AND CONCLUSIONS.—Glycerol, glycerol dichlorohydrin, phenylbiguanide, and picolinic acid have been found to antagonize or partially to inhibit the (iron) catalyzed decomposition of DDT-kerosene spray deposits on grapefruit and navel orange leaves in the field; the picolinic acid exhibited pronounced inhibiting properties. These materials were ordinarily used at 5 per cent of the weight of the DDT in the spray mixture, although both glycerol and phenylbiguanide were tested at several concentrations. The available evidence indicates that the manner in which the spray mixture is formulated may be critical to the optimum field performance of the inhibitor.

Evidence to date suggests that these four compounds in particular are worthy of further study as DDT-decomposition inhibitors. It is hoped that the present preliminary report will convey to other investigators the suggestion of potential merit in this application, with especial reference to picolinic acid.

A reasonable explanation of the key chemical reaction involved in the field decomposition of DDT under defined conditions is presented to substantiate the concept concerning a probable site of interference by these materials. Both the mechanism and the nature of this interference remain obscure.

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A New Evaluation Method for Acaricides Using the Red Spider Mite

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The red spider mite problem often becomes acute following the use of certain of the newer organic insecticides, especially DDT, on a variety of agricultural crops and this has stimulated new searches for more effective acaricides. These searches have been handicapped by the lack of a more satisfactory laboratory testing technique. While a number of techniques in which mites were used as test animals have been published (Siegler 1947, Yerington & Gertler 1948), they

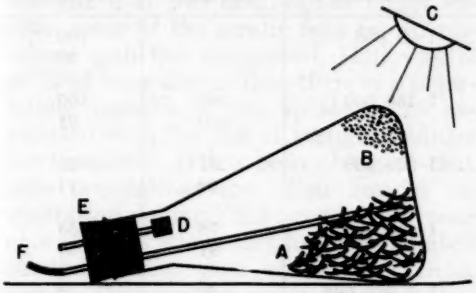

FIG. 1.—Diagram of Erlenmeyer set up for drying mite-infested bean leaves. A, Bean leaves. B, Mites concentrating at light. C, Ligt. D, Screen wire guard. E, Rubber stopper. F, Lead to compressed air line.

are for the most part designed for screening tests and are not adapted to separating compounds of similar toxicities.

In some studies on tetraethyl pyrophosphate, which is non-ovicidal and only slightly toxic to quiescent forms, but highly toxic to active forms of the red spider mite, it became apparent that in order to evaluate samples in which the tetraethyl pyrophosphate content was approximately equal, it would be necessary to devise a method in which only the active forms would be considered in the calculations. The method discussed below partly fulfills these requirements.

A culture of the two-spotted red spider mite, *Tetranychus bimaculatus* Harvey, was maintained on bush beans, *Phaseolus vulgaris* L. variety *humilis* Alef. (Tendergreen), in a greenhouse. For testing, mite-infested bean leaves are excised and place in a 4-liter erlenmeyer flask (Figs. 1 and 2). The number of leaves used depends upon the degree of infestation in the stock culture and the extensiveness of the proposed test. Generally more leaves are used than is indicated in the figures. The flask is placed on its side and closed with a two-hole rubber stopper. One hole bears

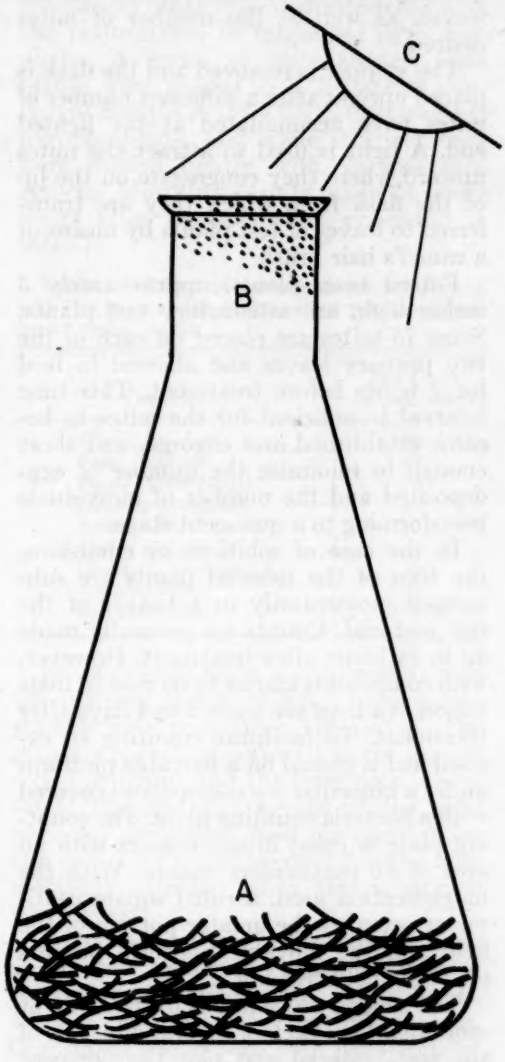

FIG. 2.—Erlenmeyer set up for attracting mites to top. A, Dry bean leaves. B, Mites. C, Light.

[1] In cooperation with Boyce Thompson Institute for Plant Research, Inc.
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a glass tube connected to a compressed air line through which air is passed at the rate of about 2 liters per minute to prevent moisture from condensing on the wall of the flask and speed the drying of the leaves. The second hole is fitted with a short piece of glass tubing through which the air escapes. The innermost end of this piece of tubing is covered with a screen wire guard to prevent leaves from closing the orifice. The mites desert the drying leaves and are attracted to an electric light (100 watt) placed near the bottom end of the flask. The drying time varies from 6 to 20 hours depending upon the quantity and moisture content of the leaves, as well as the number of mites desired.

The stopper is removed and the flask is placed upright after a sufficient number of mites have accumulated at the lighted end. A light is used to attract the mites upward where they congregate on the lip of the flask from which they are transferred to leaves of test plants by means of a camel's hair brush.

Potted bean plants, approximately 5 inches high, are satisfactory test plants. Some 75 mites are placed on each of the two primary leaves and allowed to feed for 2 hours before treatment. This time interval is sufficient for the mites to become established and engorge, and short enough to minimize the number of eggs deposited and the number of individuals transforming to a quiescent stage.

In the case of solutions or emulsions, the tops of the infested plants are submerged momentarily in a beaker of the test material. Counts are generally made 20 to 24 hours after treatment. However, with compounds known to be slow in toxic action, readings are made 2 to 4 days after treatment. To facilitate counting an excised leaf is placed on a movable platform under a binocular microscope and covered with a bacteria counting plate. The counting plate is ruled in centimeters with an area of 10 centimeters square. With the magnification used, a ruled square centimeter occupies the greater portion of the field and the movable platform permits changing fields readily.

The general procedure is to treat two or more plants in each of several dilutions of the test material and plot the per cent mortality on logarithmic probability paper. A line is fitted, by eye, to the points obtained and a LD50 established by interpolation. As a standard, a sample of pure tetraethyl pyrophosphate is similarly tested and its LD50 established for the particular group of mites. Three to five duplicate tests for each material are conducted. A set of typical data obtained by this method is presented in table 1. By comparing the average of the LD50 of the standard with that of the unknown the per cent tetraethyl pyrophosphate in the unknown is calculated.

Table 1.—Results of acaricidal tests on a sample of pure tetraethyl pyrophosphate and a commercial sample containing 37 per cent tetraethyl pyrophosphate by chemical analysis.

Dilutions	Pure	Commercial Sample
	Per Cent Mortality	Per Cent Mortality
1–80,000		100
		99
1–160,000	100	100
	100	91
1–320,000	97	66
	92	71
1–640,000	78	53
	81	40
1–1,280,000	50	3
	44	
1–2,560,000	12	
	9	

The method has been found applicable for determining the relative resistance of various species of mites to a miticide. For example, a species of *Paratetranychus* feeding on wild raspberry was found to be approximately five times as resistant to tetraethyl pyrophosphate as greenhouse-grown *Tetranychus bimaculatus* Harvey.

Summary.—A method of testing acaricides in which only the active forms are involved is discussed. Results obtained with some 30 samples of tetraethyl pyrophosphate with this bioassay method generally agreed within a few per cent with those obtained through chemical analysis. Species differences in resistance to tetraethyl pyrophosphate are noted.

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Effect of Dusts on the Performance of Tetraethyl Pyrophosphate

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In some acaricidal studies with tetraethyl pyrophosphate it was observed that when dirt was present on mite-infested bean leaves the per cent mortality was invariably low as compared to that on similarly treated clean leaves. It was thought that this observation might explain some of the erratic field results obtained with this compound. Holloway *et al.* 1942 have shown that there is a population increase of red spider mites associated with the use of certain granular inert residues. It has been observed that mite populations are often heavier on vegetation along dirt roads or near plowed fields where dirt has accumulated on the foliage than on near-by clean plants. The question arises as to whether the two phenomena, namely, mite population increase in the presence of dust and the inhibition of the toxic action of tetraethyl pyrophosphate by the presence of a dust are one and the same. The notes which follow do not answer the above question, but are concerned with the effect of the presence of dust on the toxicity of tetraethyl pyrophosphate to red spider mites.

In these studies active forms of the two-spotted red spider mite, *Tetranychus bimaculatus* Harvey, which were grown on bush bean, *Phaseolus vulgaris* L. variety *humilis* Alef. (Tendergreen), in the greenhouse, were separated and used by the method described by Melvin and Earle 1948. The effect of dust on the performance of tetraethyl pyrophosphate on the active forms of the red spider mite was determined by two methods, namely, by suspending the dust in the tetraethyl pyrophosphate solutions and by dusting the test plants before or after submerging in the dilutions.

The first test was to determine what substances other than dirt interfered with the performance of tetraethyl pyrophosphate. A series of mite-infested bean plants were dipped in a 1–160,000 dilution of Sample A (37.4 per cent tetraethyl pyrophosphate, and while still wet they were dusted lightly with various substances. Mortality counts made 24 hours hours after treatment are presented in table 1.

Table 1.—Effect of various dusts interfering with the toxic action of tetraethyl pyrophosphate to red spider mites.

TREATMENT	PER CENT MORTALITY
Check (no dust)	83
Sand (coarse)	47
Sugar (granulated)	25
Shale (pulverized)	12
Fuller's Earth	10
Coffee (soluble)	8
Quartz (pulverized)	8
Celite 209	6
Soil (fine loam)	3

In every case there was a reduction in the per cent mortality when foreign substances were present on the leaves. The greatest reduction occurred in the case of soil (fine loam) and the least with coarse sand. The size and weight of the sand particles prevented good distribution on the leaf. This might account for the high mortality attained when this substance was present.

In the second test, mite-infested bean plants were treated in various dilutions of tetraethyl pyrophosphate (Sample B, 17 per cent tetraethyl pyrophosphate). One group was dusted with pyrophyllite[1]

[1] The capable assistance of Helen Scott in the project is acknowledged.

[2] In cooperation with Boyce Thompson Institute for Plant Research, Inc.

[1] *Pyrax ABB.*

just before treatment, the second group was dusted with pyrophyllite[1] just after treatment, while the third group received no dust. The results of this test are presented in table 2.

Table 2.—Effect of pyrophyllite[1] on toxicity of tetraethyl pyrophosphate to red spider mites.

Dilution	Per Cent Mortality		
		Pyrophyllite	
	No Dust	Before Treatment	After Treatment
1–5,000	100	6	1
1–10,000	100	4	5
1–20,000	100	3	2
1–40,000	86	2	3
1–80,000	43	2	1

The above data show that the presence of pyrophyllite,[1] whether applied before or after treatment, inhibits the performance of tetraethyl pyrophosphate. To determine the effect of drying on dust interference with tetraethyl pyrophosphate performance, a series of mite-infested plants were dipped in Sample A (37.4 per cent tetraethyl pyrophosphate) diluted 1 to 160,000, and dusted with pyrophyllite at various time intervals after treatment. The results (Table 3) indicate that most of the inhibitions are lost 30 minutes after treatment. This loss could be attributed to the drying of the plant.

Results show that when dust diluents[1] or 50 per cent DDT wettable dust) are mixed with tetraethyl pyrophosphate solutions they reduce the per cent mortality. For example, one solution gave 95 per cent mortality, but when 50 per cent DDT wettable dust was added, at the rate of 4 pounds per 100 gallons, the mortality was reduced to 9 per cent.

[1] *Cherokee Clay* and *Pyrax ABB.*

Table 3.—Effect of pyrophyllite on red spider mite mortality applied at various time intervals after treatment with tetraethyl pyrophosphate.

Dilution	Pyrophyllite Applied	Per Cent Mortality
1–160,000	Just before dipping	9
	Just after dipping	8
	10 minutes after dipping	27
	30 minutes after dipping	94
	2 hours after dipping	99
	4 hours after dipping	99
	6 hours after dipping	100

Studies have also shown that the addition of wetting agents will not prevent the foreign material from interfering with the action of the tetraethyl pyrophosphate.

In preliminary tests the toxicity of parathion was reduced when mixed with 50 per cent DDT wettable dust, at the rate of 5 pounds per 100 gallons, or when plants were dusted with pyrophyllite after treatment.

Summary.—It has been demonstrated that a variety of substances when present on mite-infested plants will reduce the efficiency of tetraethyl pyrophosphate. This reduction in toxicity occurs regardless of time of application of the foreign substances as long as they are present when the plant is wet with the test solutions. The addition of wetting agents did not remedy this situation. Preliminary results indicate that parathion behaves in the same manner as does tetraethyl pyrophosphate in the presence of certain dusts.—8-31-48.

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Chlordan for Control of Japanese Beetle Larvae

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A preliminary report on chlordan for control of larvae of the Japanese beetle, *Popillia japonica* Newman, was presented last year (Fleming 1947). The investigation was continued in 1948, and the value of chlorean for the control of this insect was definitely established.

RELATIVE TOXICITY OF CHLORDAN, DDT, AND LEAD ARSENATE.—Chlordan was intimately mixed with Sassafras sandy loam at rates from 0.5 to 10 pounds per acre, DDT at rates from 5 to 50 pounds per acre, and lead arsenate at 500 and 1000 pounds per acre. The volume of soil in an acre to a depth of 3 inches, 10,890 cubic feet, was used as a basis for these treatments. One hundred and fifty third-instar larvae were used in each treatment, and at intervals the numbers of dead and living larvae were determined. The experiment was repeated until more than 1000 larvae had been subjected to each treatment. After adjustment of mortalities for the death rate in untreated soil, the number of days required for each treatment to kill 50 per cent of the larvae was determined.

The results are presented graphically in figure 1. By interpolation it was estimated that 9.5 pounds of DDT killed at the same rate as 1000 pounds of lead arsenate, and 0.7 pound of chlordan at the same rate as 50 pounds of DDT. It would appear, therefore, that chlordan is about 70 times as toxic as DDT and about 7000 times as toxic as lead arsenate.

DURATION OF EFFECTIVENESS OF CHLORDAN.—Plots treated with lead arsenate or DDT have been practically free of Japanese beetle grubs for 3 to 5 years. To be practical, therefore, a treatment with chlordan should remain effective for more than one season. To determine the period of effectiveness of different amount of chlordan, this material was intimately mixed with soil at rates varying from 8 ounces to 10 pounds per acre, and third-instar larvae were introduced immediately after treatment and at intervals up to 52 weeks. The time required to kill 98 per cent of the larvae in each group was determined. (Fig. 2.) The velocity of insecticidal action was significantly reduced with the 8-ounce treatment in 4 weeks, with the 1-pound treatment in 8 weeks, and with the 5-pound treatment in 40 weeks. The 10-pound treatment showed no significant change in 52 weeks. A practical treatment will require at least 10 pounds of chlordan per acre.

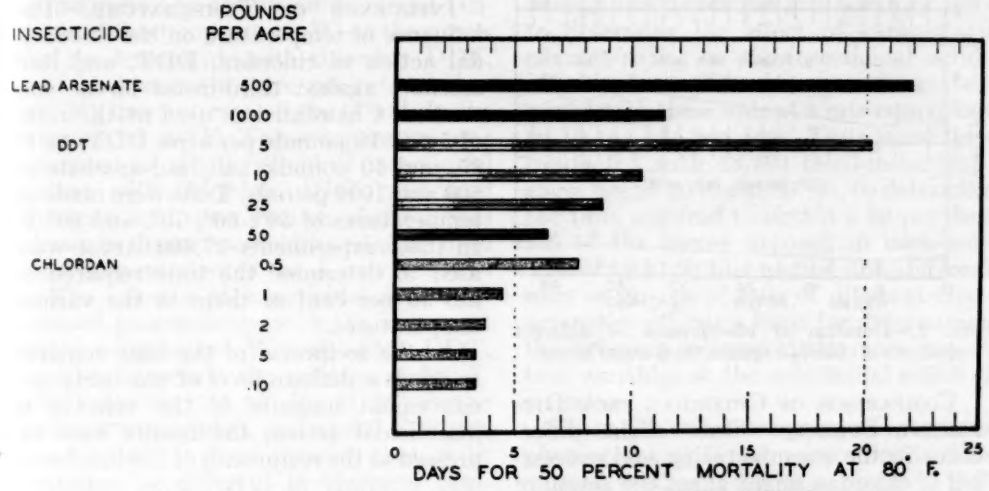

FIG. 1. Toxicity to third-instar larvae of lead arsenate, DDT and chlordan.

[1] The writer acknowledges the assistance of his associates a the Japanese Beetle Laboratory, especially Arthur C. Mason and Warren W. Maines for their part in the investigation and Lawrence B. Parker for preparing photographs. The Connecticut (New Haven) Agricultural Experiment Station cooperated in obtaining representative types of soil and in locating sites for experimental plots in that state, and the Massachusetts Agricultural Experiment Station obtained representative types of soil from that state.

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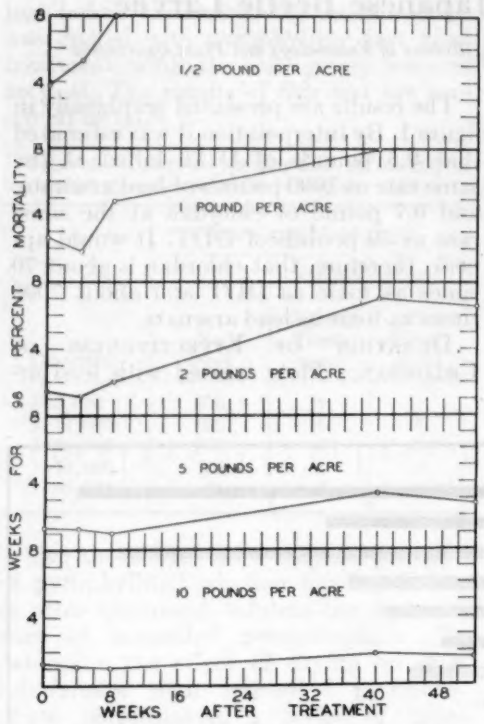

FIG. 2.—Duration of effectiveness of different amounts of chlordan against third-instar larvae

COMPARISON OF CHLORDAN FROM DIFFERENT SOURCES.—Since slight differences in the manufacturing and processing of chlordan might affect the action of this insecticide, a laboratory study was made of two 5-per cent dusts which had been made from the technical product of the two principal manufacturers. Each material was intimately mixed with Sassafras sandy loam at rates equivalent to 5 and 10 pounds of chlordan per acre. Five hundred third-instar larvae, divided into 10 groups, were used in each treatment. After 4 days the average survival in the 5-pound treatment was 17.2 ± 3.4 per cent with one material and 18.4 ± 4.0 per cent with the other, and in the 10-pound treatment the survival was 9.8 per cent with both materials.

Chlordan dusts from four sources were tested in field plots in 1947 and 1948 with no difference in effectiveness.

COMPARISON OF FORMULATIONS.—In the spring chlordan was applied to turf as a dust, a suspension, and an emulsion at the rate of 10 pounds per acre to compare the effectiveness of the different formulations. The dust contained 5 per cent of chlordan. The suspension was prepared by adding 25 pounds of 40 per cent wettable powder, and the emulsion by adding 10 pounds of emulsion concentrate to 1200 gallons of water. Within 3 weeks the average reduction in the population was 66 per cent from the dust, 68 per cent with the suspension, and 65 per cent from the emulsion. The next brood of larvae was eliminated by mid-September in all the plots. Treatments made with the dust or the suspension late in September caused a reduction of 93 per cent in 3 weeks. Chlordan is equally effective when applied to turf as a dust, suspension, or emulsion.

INFLUENCE OF TEMPERATURE.—The influence of temperature on the insecticidal action of chlordan, DDT, and lead arsenate against third-instar larvae was studied. Chlordan was used at the rates of 5 and 10 pounds per acre, DDT, at 10 25, and 50 pounds, and lead arsenate at 500 and 1000 pounds. Tests were made at temperatures of 50°, 60°, 70°, and 80° F. In these experiments 27,800 larvae were used to determine the time required to kill 50 per cent of them at the various temperatures.

As the reciprocal of the time required to reach a definite level of mortality is a convenient measure of the velocity of insecticidal action, the results were expressed as the reciprocals of the number of

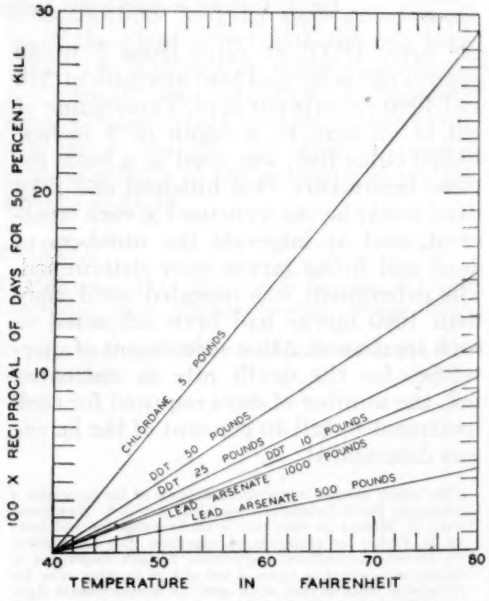

FIG. 3. Velocity of insecticidal action of chlordan, DDT and lead arsenate against third-instar larvae.

days, multiplied by 100 to avoid fractions, and plotted against the corresponding temperatures. The slopes of these lines were determined by the method of least squares. The curves for the different treatments are given in figure 3.

The minimum temperature at which larvae are sufficiently active to be poisoned is important, in that it limits the period of insecticidal action in the spring and in the fall. It would be very difficult experimentally to determine the temperature above which poisoning by these materials would be perceptible, but it is possible from the reciprocal time-temperature curves to obtain an empirical estimate of this temperature. When the curves for the treatments with chlordan, DDT, and lead arsenate were projected below 50° F., they intersected the *X* axis in the vicinity of 40° F. This temperature was accepted as the threshold of insecticidal action with chlordan, DDT, and lead arsenate, and the elevation of the curves shown in figure 3 was adjusted slightly so that they intersected the *X* axis at 40° F.

The velocity of insecticidal action increased progressively with the increment in the temperature. With chlordan, DDT, and lead arsenate the velocity at 60° F. was twice that at 50° F.; at 70° F. the velocity was tripled, and at 80° F. it was quadrupled. It is of interest that, with materials so different in chemical composition, the velocity of insecticidal action is influenced in the same manner by the temperature.

At each temperature above the empirical threshold the velocity of insecticidal action with 5 pounds of chlordan was 2.5 times as fast as with 25 pounds of DDT, 3.25 times as fast as with 1000 pounds of lead arsenate, and 6.25 times as fast as with 500 pounds of lead arsenate. The velocity of poisoning with 5 pounds of chlordan at 50° F. was of the same order as with 25 pounds of DDT at 65° F. and with 1000 pounds of lead arsenate at 70° F.

EFFECT OF SOIL CHARACTERISTICS ON THE INSECTICIDAL ACTION OF CHLORDAN.—Samples of 44 soils were collected from different physiographic provinces in New Jersey, New York, Connecticut, and Massachusetts for use in laboratory tests to determine the effect of various soil characteristics on the insecticidal action of chlordan. Chlordan was intimately mixed with these soils at a rate equivalent to 10 pounds per acre. Tests were then conducted with 13,200 third-instar Japanese beetle larvae at 80° F., to determine the time required to obtain a 98-per cent kill of the larvae exposed in each soil. The length of this period for different soils or groups of soils of different characteristics affords a basis for determining the influence of some of the more important variables on the insecticidal action of chlordan.

When the soils were grouped into their physiographic provinces according to their natural drainage, the data revealed that in most ceses a slightly longer period was required to kill larvae in poorly drained soils than in the well-drained, adequately aerated soils (Fig. 4), probably because

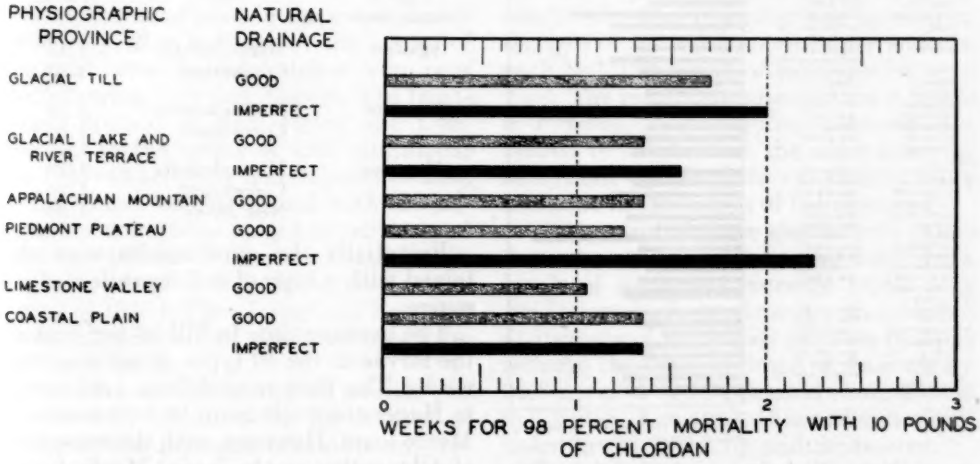

FIG. 4. Influence of origin and natural drainage of soil on the effectiveness of chlordan against third-instar larvae.

of the higher content of organic matter in the poorly drained soils. Under natural conditions an excessive amount of water in soils would further inhibit insecticidal action. Larvae move less when searching for food in soils rich in organic matter than in soils made up largely of mineral aggregates, and have less opportunity to encounter particles of the insecticide. The average time to kill the larvae in all soils was 1.4 weeks. In the well-drained soils the time ranged from 1 week in the Limestone Valley soils to 1.7 weeks in the Glacial Till soils, and in the imperfectly drained soils from 1.4 weeks in the Coastal Plain soils to 2.2 weeks in the Piedmont Plateau soils. However, the variations within the physiographic provinces were as great as the differences between them. The results obtained thus far indicate that the origin of the soil is not an important factor limiting the effectiveness of chlordan.

Soils that are uniform with reference to the material from which they were formed, the agency of formation, the nature of the horizons, the chemical composition, organic matter, and other factors, but differ in the texture of the surface horizon, constitute a soil series. Soils that are essentially uniform in all respects, including the texture of the surface layer, constitute a soil type. When the soils were grouped according to their texture into sands, gravelly and shale loams, sandy loams, loams, and silt loams, the velocity of insecticidal action was found to decrease only slightly with the increment in the proportion of silt and clay in the soil (Fig. 5). The average time in the sands was 1.25 weeks and in the silt loams 1.49 weeks. The texture of the soil seemed to be relatively unimportant.

FIG. 5.—Influence of soil type and texture on the effectiveness of chlordan to third-instar larvae.

Three of the types of soil under test—Agawam sandy loam, Cheshire sandy loam, and Merrimac sandy loam—were obtained from more than one state. Thus an opportunity was given to compare the effectiveness of chlordan in the same soil type from widely separated localities. The time required to kill 98 per cent of the larvae in the three soil types at the different localities was as follows:

Type of sandy loam	*State*	*Weeks*
Agawam	Massachusetts	1.15
	Connecticut	1.15
Cheshire	Massachusetts	1.55
	Connecticut	1.80
Merrimac	Massachusetts	1.70
	Connecticut	1.30
	New Jersey	1.35

Essentially the same results were obtained with a type of soil regardless of its source.

The average time to kill 98 per cent of the larvae in the 40 types of soil was 1.45 weeks. The time ranged from 1.05 weeks in Hagerstown silt loam to 2.70 weeks in Menlo loam. However, with the exception of Gloucester sandy loam, Menlo loam, and Croton silt loam, this level of mor-

tality was obtained in all types of soil within 1 to 2 weeks. The type of soil seems to have little influence on the rate of insecticidal action.

CONTROL OF JAPANESE BEETLE LARVAE IN TURF.—In the spring of 1947 chlordan was applied to establish turf at Blairstown, N. J., and Orange and New London, Conn., in the fall of 1947 at Northampton, and Deerfield, Mass., and Moorestown, N. J., and in the spring of 1948 at Moorestown, N. J., and Philadelphia, Pa. Applications were made at the rate of 10 pounds per acre. Surveys have been made periodically in these turf plots to determine the effect of the treatment on the larvae. The results obtained at these widely separated localities have been uniformly good. Owing to the extremely dry conditions throughout New England in the fall of 1948, it was impossible to make an adequate survey at that time in this area.

The results may be summarized briefly as follows: A treatment applied in March when the larvae were inactive caused a reduction in the population of 12 per cent in 5 weeks, 87 per cent in 9 weeks, and over 90 per cent before pupation. A treatment applied the middle of May caused a reduction of 65 per cent in 3 weeks and over 90 per cent in 4 weeks. A treatment applied in September, while the larvae were active, caused a reduction of more than 90 per cent within 3 weeks, but a treatment applied late in October, when the larvae were relatively deep in the soil and beginning to hibernate, did not reduce the population to this extent until the following May.

Treatments applied in the spring or fall were very effective against the larvae of the next brood, which hatched from eggs the following July and August. The treatments applied in New Jersey and Connecticut in the spring of 1947 eliminated the 1947–48 brood by mid-September and, so far as can be determined with the adverse soil conditions, they have eliminated the 1948–49 brood. Treatments applied in the fall of 1947 in New Jersey and in the spring of 1948 in New Jersey and Pennsylvania eliminated the 1948–49 brood by mid-September.

Chlordan at the rate of 10 pounds per acre is very effective for the control of larvae of the Japanese beetle in turf, reducing the infestation faster than either lead arsenate or DDT. It is not known how long the treatment will keep turf immune from injury by these larvae, but present indications are that it will be effective for at least 2 years.

CONTROL OF JAPANESE BEETLE LARVAE IN NURSERY SOILS.—Chlordan was applied to established blocks of nursery stock in commercial nurseries near Bridgeton, N. J. The material was applied as a dust at the rate of 10 pounds per acre and mixed by cultivation with the upper 3 to 4 inches of soil. Applications were made in April, May, July, and August to determine how late a treatment could be made to eliminate larvae that hatched during July and August. The April treatment reduced the 1947–48 brood by 84 per cent in 4 weeks and eliminated it in 7 weeks. Treatment as late as August 9 eliminated the infestation of the 1948–49 brood by mid-September.

These results indicate that chlordan will have a role in the treatment of ornamental nursery stock for control of this insect.

CONTROL OF WHITE GRUBS ASSOCIATED WITH THE JAPANESE BEETLE.—Information was also obtained on the effectiveness of chlordan in controlling white grubs associated with the Japanese beetle, although only a few grubs of other species were found.

In a preliminary laboratory test the velocity of insecticidal action of chlordan on the oriental beetle, *Anomala orientalis* Waterhouse, the Asiatic garden beetle, *Autoserica castanea* Arrow, and *Cyclocephala borealis* Arrow was compared with that on *Popillia japonica* under the same conditions. The chlordan was applied in dosages of 10 and 20 pounds per acre. In each test 150 larvae of each species were used. The results are summarized in figure 6. *Popillia*, *Anomala*, and *Autoserica* appeared to be of about the same susceptibility, but *Cyclocephala* was slightly more resistant to the action of the chemical.

The control of these species with chlordan was studied also in the field. In a block of evergreen nursery stock near Bridgeton, N. J., treatment with chlordan at the rate of 10 pounds per acre in April reduced the 1947–48 brood of *Anomala* by 98.6 per cent in 4 weeks and eliminated it in 7 weeks. The 1948–49 brood was eliminated in this block by mid-September.

Turf infested with *Popillia* and *Autoserica* at Moorestown, N. J., was treated

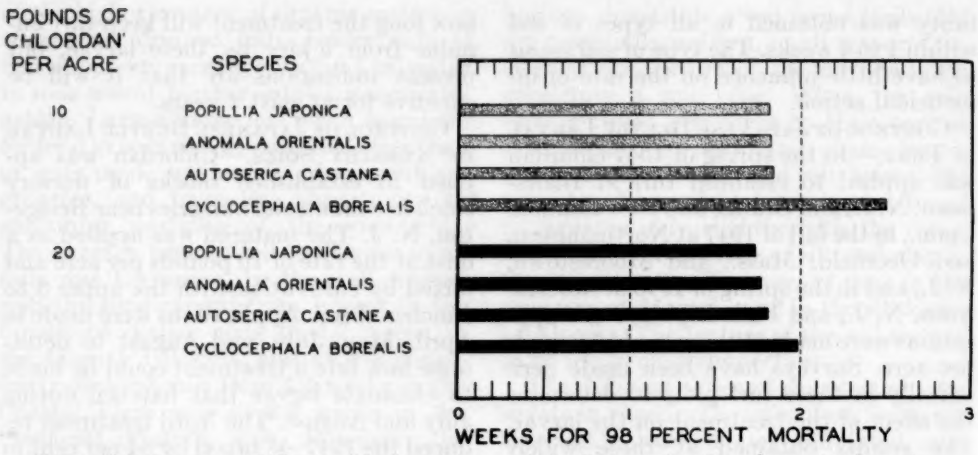

FIG. 6. Relative susceptibility to chlordan of larvae of the Japanese beetle and associated species.

with chlordan at the rate of 10 pounds per acre in March, before the larvae became active. The treatment had little effect on either species during the following 4 weeks but after 9 weeks there was a reduction of 87 per cent in the *Popillia* and 68 per cent in the *Autoserica*, and after 13 weeks reductions of 98.5 per cent and 97.4 per cent respectively. The 1948–49 broods of these species were eliminated by mid-September.

In another test, turf at Philadelphia infested with *Popillia*, *Autoserica*, and *Cyclocephala* was treated in May with chlordan at the rate of 10 pounds per acre. Three weeks later there was a reduction of 66 per cent in *Popillia* and 70 per cent in *Cyclocephala*. The effect on the *Autoserica* could not be evaluated because of the light population. By mid-September this treatment had eliminated the 1948–49 broods of *Popillia* and *Autoserica* and had caused a reduction of 99.5 per cent in *Cyclocephala*.

These results indicate that a treatment with chlordan for the control of Japanese beetle larvae would be effective against infestations of *Anomala orientalis*, *Autoserica castanea*, and *Cyclocephala borealis*.

EFFECT ON PLANTS OF CHLORDAN IN SOIL.—In preliminary tests chlordan applied to the surface at the rate of 25 pounds per acre had no effect on the color, general appearance, or growth of the following grasses: Redtop, Colonial bentgrass, Astoria bentgrass, Bermuda grass, orchard grass, meadow fescue, Chewings fescue, perennial ryegrass, Canada bluegrass, Kentucky bluegrass, and rough stalk bluegrass. During 18 months no injury with chlordan at the rate of 10 pounds per acre was observed on lawns and golf courses of mixed grasses at Blairstown or Moorestown, N. J., Orange or New London, Conn., Deerfield or Northampton, Mass., or Philadelphia, Pa. Twenty pounds of chlordan per acre had no effect on a lawn of mixed grasses at Moorestown. Forty pounds per acre had no effect on a lawn of mixed grasses at Rye, N. Y., but caused slight yellowing of a mixture of bent grasses and of velvet bent on greens at Philadelphia. The discoloring was more pronounced when chlordan was used at the rate of 80 pounds per acre. However, this discoloration disappeared in a month.

Field crops.—Chlordan mixed with the upper 3 inches of soil at 10 and 20 pounds per acre had no significant effect during the first year on the germination, growth, and yield of spring rye or on the germination or growth of soybeans of the Black Wilson type and hybrid field corn, Funk G-94. When the rye was harvested, the yield of straw and grain was 1.34 tons per acre in the plots receiving the 10-pound treatment, 1.22 tons in plots getting the 20-pound treatment, and 1.34 tons in the untreated plots. The yield of field-corn ears was 4.13 tons per acre in the treated plots and 4.07 tons in the untreated plots.

Garden vegetables.—Preliminary tests were made with 20 garden vegetables to determine their reaction to chlordan mixed into the soil. All of them germinated normally. Fifteen of the vegetables grew normally in soil treated with 20 pounds per acre, including green-pod bush beans, beets, broccoli, cabbage, carrots, chili

corn, kale, muskmelon, onions, peppers, radishes, tomatoes, turnips, and watermelon. Two of them, lima beans and eggplant, were retarded by the 20-pound treatment but grew normally in soil given the 10-pound treatment. Celery was retarded when more than 5 pounds of chlordan was applied per acre, and cucumbers and squash were retarded by the 5-pound treatment.

Strawberries.—Three varieties of strawberries were grown in soil treated with chlordan. Gandy grew normally in soil treated at the rate of 20 pounds per acre, Maytime was retarded by this treatment but grew normally in soil given the 10-pound treatment, and Massey was retarded to some extent by the 10-pound treatment.

Annuals.—Preliminary tests were made with 20 annuals. All germinated normally. Seventeen of them grew normally in the 20-pound per acre treatment, namely, aster, calendula, candytuft, centaurea, chrysanthemum, cosmos, gaillardia, hollyhock, nasturtium, pansy, portulaca, pyrethrum, scabiosa, sweetpea, sweet william verbena, and zinnia. Pinks were retarded by the 20-pound treatment, but grew normally in the soil receiving the 10-pound treatment. Oriental poppy and snapdragon were retarded by the 5-pound treatment.

Greenhouse plants.—In preliminary tests at a commercial nursery, Australian brake and cyclamen grew normally in soil treated with 10 pounds of chlordan per acre.

Nursery stock.—In preliminary tests at a commercial nursery, 7 varieties of azaleas of the Kurume and Indica types grew normally in the soil getting the 10-pound treatment, namely, Coralbells, Dr. Bergman, Hinodigiri, Mme. Petrick, Mme. Sanders, Mme. Vandercruyssen, and Simon Mardner.

In large-scale tests in the field at commercial nurseries, over 28,000 evergreens of the following varieties were grown successfully in soil treated with 10 pounds of chlordan per acre: Common box, scarab Lawson false cypress, golden Lawson false cypress, blue Nootka false cypress, slender Hinoki false cypress, dwarf Hinoki false cypress, Sawara false cypress, golden Sawara false cypress, plume Sawara false cypress, silvertip Sawara false cypress, graymoss Sawara false cypress, Irish Juniper, Hill eastern red cedar, Japanese yew, Hunnewell yew, Hatfield Anglojap yew, George Peabody eastern arborvitae, Tom Thumb eastern arborvitae, Berckmanns oriental arborvitae, Baker oriental arborvitae, and Newark oriental arborvitae.

SUMMARY.—Studies initiated in 1947 to determine the value of chlordan for the control of the Japanese beetle were continued in 1948 at Moorestown, N. J.

Chlordan appeared to be 70 times as toxic as DDT and 7000 times as toxic as lead arsenate to larvae of the Japanese beetle, *Popillia japonica* Newman, when freshly applied. However, when the duration of effectiveness was considered, it was evident that at least 10 pounds of chlordan per acre was required.

Chlordan had the same effectiveness regardless of the source of the material or the form—dust, suspension, or emulsion—in which it was applied.

The velocity of insecticidal action with chlordan, as with DDT and lead arsenate, increased with the temperature of the soil. A temperature of 40° F. appeared to be the threshold of insecticidal action against the larvae. The insecticidal action with 5 pounds of chlordan was 2.5 times as fast as with 25 pounds of DDT, and 6.25 times as fast as with 500 pounds of lead arsenate per acre.

The velocity of insecticidal action of chlordan was not modified significantly by the origin or texture of the soil, but was retarded in poorly drained, inadequately aerated soils. The composition of the mineral aggregates in the various soils seemed to have little influence on chlordan, but organic matter retarded the insecticidal action. Essentially the same results were obtained in a given type of soil wherever it occurred. Although the type of soil had some influence on the insecticidal action, in general the type seemed relatively unimportant.

Chlordan at 10 pounds per acre was very effective in controlling larvae of the Japanese beetle in turf. From present indications it will keep turf immune from injury for at least 2 years.

Chlordan at 10 pounds per acre, applied as late as August 9, eliminated infestations of Japanese beetle larvae in blocks of ornamental nursery stock by mid-September.

The treatment for control of Japanese beetle larvae was effective against larvae of *Anomala orientalis* Waterhouse, *Auto-*

serica castanea Arrow, and *Cyclocephala borealis* Arrow.

When applied at the rate of 10 pounds per acre chlordan had no effect on the common grasses, spring rye, soybeans, hybrid corn, evergreen nursery stock, or most of the garden vegetables, strawberries, and annuals that were tested.

Chlordan is one of the most effective materials for control of Japanese beetle larvae. It kills faster than DDT or lead arsenate. It is not seriously affected by conditions in the soil. Most plants seem to be tolerant of it. Chlordan should be one of the most valuable materials for control of this pest in turf and in plots of ornamental nursery stock.

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Benzene Hexachloride—DDT Combination Dust for Pest Control

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Combination dusts of benzene hexachloride and DDT have been used in many incidental tests for pest control in North Carolina. This paper is a summary of the results obtained by using such combination dusts as well as some other dusts, namely, chlorinated camphene, chlordan, benzene hexachloride and DDT. Spray formulations used in these tests included hexaethyl tetraphosphate and DDT.

The insect pests against which these insecticides were used were as follows:

The lesser corn stalk borer—in late snap beans.

Aphids—on seedling cotton, also on mature tobacco and *Lotus uliginosus*, a legume.

Three—cornered alfalfa hopper—on nursery plantings of alfalfa.

Thrips—on seedling cotton.

THE LESSER CORN STALK BORER, *Elasmopalpus lignosellus* (Zell.).—Late plantings of snap beans and other vegetables are frequently riddled by the work of this pest. An experimental planting of snap beans in early September was heavily infested with the lesser corn stalk borer. On September 1, treatments were made with a spray diluted from 50 per cent wettable DDT powder and with a combination dust of 3 per cent benzene hexachloride and 5 per cent DDT. The spray was diluted as follows: 60 grams of 50 per cent wettable DDT powder per gallon. The diluted spray was applied to the base of the plants at the rate of 1 gallon per 50 feet of row. The dust was applied to the rows of the plants with a rotary type hand gun at the rate of about 10 pounds per acre. Each plot consisted of 50 feet of row and each treatment was replicated 3 times. Plants were examined at 4 hours after treatment and again at 24 hours after treatment. A sufficient number of plants were examined in order to observe at least 10 larvae in each treatment. The results of these 2 examinations are listed in table 1.

Table 1.—Number of lesser corn stalk borers at 4 and 24 hours after treatment.

TREATMENT	TIME AFTER TREATMENT			
	4 Hours No. Borers		24 Hours No. Borers	
	Alive	Dead	Alive	Dead
DDT spray—60 grams of 50% wettable to 1 gal. water	8	2	7	3
3% gamma Benzene hexachloride —5% DDT	6	4	6	4
Untreated check	10	0	10	0

The action of the combination benzene hexachloride-DDT dust on stalk borers was more pronounced than that of the DDT spray. This was clearly evident in the field observations. In the DDT replicates no larvae were found outside the plant but they were easily found in the plant. This indicated that larvae were not immediately affected by the DDT spray treatment. In each of the benzene hexachloride-DDT dust treated rows, numerous larvae were found in the row outside the plant and they had symptoms of poisoning. Their bodies twitched abnormally and they were not capable of

coordinated movements. No injury to the beans from the use of either insecticide was noted. After 24 hours the two treatments appeared equally effective.

APHID CONTROL.—Numerous instances of aphid injury were reported to the Station during 1947 season. A severe infestation of the cotton aphid, *Aphis gossypii* Glover, in seedling cotton was controlled with a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT. This combination dust did an equally good job of control on thrips infesting seedling cotton.

Aphids (undetermined species) attacking experimental cage plantings of *Lotus uliginosus* were cleared up with a combination dust of 1 per cent gamma benzene hexachloride and 5 per cent DDT.

Aphids (probably the green peach aphid, *Myzus persicae* (Sulz)) were a problem in many tobacco fields late in the season. Aphid abundance was at a peak right at or just before the priming of tobacco. Nicotine sulfate, 40 per cent, one part to 800 parts water by volume, did not give any noticeable control of aphids in one badly infested field. Some of the more heavily infested and previously untreated plants in this field were selected for tests with other insecticides. The following insecticides were used:

(a) Gamma benzene hexachloride dust, 0.8 per cent
(b) Hexaethyl tetraphosphate 0.1 per cent spray
(c) Combination dust of 1 per cent gamma benzene hexachloride and 5 per cent DDT.

Dusts were applied with a plunger type hand duster; the spray with a small compressor type garden sprayer of one gallon capacity. No record was kept of the actual amount of material used per plant but complete coverage of the plant was obtained with either the spray or dust.

Within 5 days a noticeable reduction of aphids in all treatments had taken place. Counts of aphids in a sample of 10 plants out of each treatment showed that the hexaethyl tetraphosphate treated plants had the largest number of live aphids 5 days after treatment. The 0.8 per cent benzene hexachloride treated plants had fewer aphids than the hexaethyl tetraphosphate treated plants. The smallest number of aphids was noted on the plants treated with the combination dust of 1 per cent gamma benzene hexachloride and 5 per cent DDT.

No plant injury was observed by the spray treatment with hexaethyl tetraphosphate. Some leaf injury was noted with either of the dusts. Because of the persistent odor of benzene hexachloride, it is possible that tobacco treated with benzene hexachloride spray or dust may be tainted with the odor of this material. Tobacco thus flavored would not be suitable or desirable for regular use.

In another test for aphid control on tobacco two others dusts were used, (a) 5 per cent chlorinated camphene and (b) 5 per cent chlordan. Applications with a plunger type hand duster were made to 10 single plant replicates. A count of aphids 24 hours after treatment showed an average reduction in aphids of 70 per cent in each treatment. Heavy rain falling shortly after this examination washed off the remaining aphids. No tests for insecticidal residues were made with the tobacco in these 2 treatments.

THE THREE-CORNERED ALFALFA TREEHOPPER (POSSIBLY *Stictocephala festina* (SAY)).—Adults and nymphs were found attacking experimental plantings of alfalfa and several alfalfa fields in the vicinity of Raleigh. Injury occurred late in the season and consisted of a girdling of the stem at one or two places at 1 to 2 inches above the ground level. In experimental nursery plantings, an infestation was controlled by one dusting with a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT applied with a rotary type hand duster at about 10 pounds per acre.

SUMMARY.—The following pests were controlled with a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT: the lesser corn stalk borer, in late snap beans; aphids and thrips on seedling cotton; and the three-cornered alfalfa hopper on alfalfa. A 1 per cent gamma benzene hexachloride and 5 per cent DDT dust combination controlled an aphid infestation on cage plantings of *Lotus uliginosus*. This combination dust was more effective in controlling late infestations of aphids on tobacco at 5 days after application than was a 0.1 per cent hexaethyl tetraphosphate spray or a 0.8 per cent gamma benzene hexachloride dust. 7-12-48.

Experiments With Insecticides Against the Sugarcane Borer in 1947[1]

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Testing of new insecticides was continued in field plots of sugarcane in Louisiana during 1947 to find a more effective and less expensive material than cryolite for use in the control of the sugarcane borer, *Diatraea saccharalis* (F). Cryolite is widely used for this purpose in Louisiana, but, in addition to being rather expensive, it sometimes permits heavy increases in infestations of the yellow sugarcane aphid, *Sipha flava* (Forbes), or causes some foliage injury. Small-plot and large-scale experiments with several of these new insecticides are reported in this paper.

Methods.—In the small-plot experiments each treatment was replicated not less than five or more than eight times in experiments of a latin square or randomized-block design. Some of the experiments were conducted in the spring against first-generation borers, and some were conducted against third- and fourth-generation borers in summer-planted cane in September, when it is similar in size and growth to cane at the time of first-generation injury. Twentieth-acre plots were used, and usually the insecticides were applied four times at weekly intervals, beginning with the hatching of the first eggs. When a dust was used, it was applied at the rate of approximately 8 pounds per acre. The number of live borers surviving treatment was determined by dissecting all dead cane shoots, called dead hearts, in equal lengths of row on each plot, leaving buffer areas 6 feet wide on each side and 3 feet wide on each end. The dead hearts contain more than 95 per cent of all borers surviving in the young growth present in the spring on established stands, or in September on new plantings made the preceding summer.

Other small-plot experiments were conducted against second- or third-generation borers in tall cane. Thirtieth-acre plots were used for these tests, and usually each insecticide was applied four times at weekly intervals, beginning with the hatching of the first eggs. All dusts tested were applied at the rate of 10 pounds per acre. Control was determined by counting the bored and nonbored joints (internodes) of cane in 50 stalks per plot. Determination of sucrose content and total weight of cane were obtained in one of these small-plot experiments.

In the large-acreage experiments entire cuts were dusted by airplane. A cut was approximately 2 acres bounded by roadways on each end and ditches on each side. These experiments were conducted against first-generation borers. There were several replications of each treatment. The number of borers surviving treatment was determined by dissecting all dead shoots on two rows for the entire length of the cut (about 1300 row feet), the rows being one-third and two-thirds of the distance from one side of the cut. Later examinations consisted in determining the number of bored and nonbored joints of cane in 100 representative stalks from each cut. Samples of cane for determining the sucrose content and the total weight of cane from each cut were obtained at harvest-time.

Yellow sugarcane aphid populations following various treatments were determined by examining the fourth leaf below the central whorl on 10 consecutive sugarcane plants in each of 10 representative locations in each plot. Each leaf examined was recorded as having no aphids, a few aphids (1 to 10), a medium infestation (11 to 50), or a heavy infestation (more than 50 aphids per leaf).

Ryania.—In 1945 undiluted *Ryania* dust gave much better control of second-generation borers than did cryolite, and 25-per cent *Ryania* dust was apparently somewhat more effective than cryolite against third-generation borers. In 1946 a dust containing 50 per cent of *Ryania* applied three times at 10-day intervals against first-generation borers gave about the same control as cryolite applied the usual four times at 7-day intervals. A dust containing 25 per cent of *Ryania*

[1] Cotton States Program 1948.
[2] W. E. Haley collaborated in the project here reported.

Table 1.—Percentage control of indicated generations of the sugarcane borer obtained with various insecticides (dusts unless otherwise indicated). Small-plot experiments.

INSECTICIDES (PER CENT OF ACTIVE INGREDIENT)		GENERATIONS			
		First	Second	Third	Third and Fourth, in Summer-Planted Cane
Ryania	40	67, 67, 82, 89, 49,[1] 59[1]	86	—	63, 86
Ryania extractives	40	—	—	—	65
Ryania spray[2]		98	—	—	—
Benzene hexachloride (gamma isomer)	2	92, 77, 87, 79, 78,[1] 79,[1] 97[3]	72	—	72
	1	69, 46	—	—	—
	3	77,[1] 80[1]	—	—	—
Chlorinated camphene	10	91, 92, 88, 78 85,[1] 78,[1] 96[4]	74, 38 40	—	24, 70
	7	80, 74	—	—	—
	15	89,[1] 85[1]	—	—	—
	20	—	—	—	87
Synthetic cryolite (90% sodium fluoaluminate)		72, 73, 91, 89 90	76, 75 67	18	65, 89
Parathion	2	—	—	5	−2, 52
	1	—	—	1	20
3,4-Dichlorobenzenesulfone *p*-nitroanilide	5	23	—	—	—
Sulfur		—	49[5]	—	—
2,4-D	10	17, 27	58[5]	0	40

[1] Applied 3 times at 10-day intervals.
[2] 5 pounds of undiluted wettable *Ryania* in 80 gallons of water per acre.
[3] 3.33 pounds of wettable benzene hexachloride containing 6 per cent of the gamma isomer in 80 gallons of water per acre.
[4] 4 pounds of 25 per cent wettable chlorinated camphene in 80 gallons of water per acre.
[5] Increase.

gave poorer or no better control than cryolite. On summer-planted cane the 50-per cent *Ryania* dust and cryolite gave about equal control.

The results of the experiments with *Ryania* in 1947 are summarized in table 1 (small-plot) and in table 2 (large-scale). Unless otherwise indicated, each insecticide was applied as a dust four times at weekly intervals. Data on aphid abundance following treatment are given in table 3. A dust containing 40 per cent of *Ryania* gave control equal to that of an undiluted cryolite dust in one small-plot experiment on first-generation borers, but less control in the other three experiments, with *Ryania* averaging 76 per cent control and cryolite 81 per cent control. In two experiments *Ryania* dust applied three times at 10-day intervals failed to give as good control as cryolite. Undiluted wettable *Ryania* applied at the rate of 5 pounds in 80 gallons of water per acre gave better control of first-generation borers than cryolite dust. On third- and fourth-generation borers in summer-planted cane 40-per cent *Ryania* dust gave slightly less control than cryolite in each of two experiments. Forty-per cent *Ryania* dust gave better control of second-generation borers than cryolite.

In an airplane dusting experiment (table 2) 40 per cent *Ryania* gave less control of first-generation borers than cryolite and the harvest time infestation was slightly higher than it was with cryolite; however, the yield of sugar per acre was 112 pounds greater in the *Ryania*-treated plots. The infestation of second-generation borers following dusting and at harvest time was about the same in plots treated with 40 per cent *Ryania* and with cryolite, but the yield of sugar per acre was 110 pounds less with *Ryania* than with cryolite.

Data obtained in 1947 and in previous

Table 2.—Effect of various insecticidal dusts on control of the sugarcane borer, harvest time infestation, and yield of sugar per acre as compared with cryolite.

Insecticide (Figures Indicate Per Cent of Active Ingredient)		Number of Plots	Per Cent Control of Borers Compared With Cryolite in Same Experiment[1]	Per Cent Control at Harvest Based on Infestation and Compared With Cryolite in Same Experiment[2]	Increase or Decrease (Pounds) in Yield of Sugar per Acre as Compared With Cryolite in Same Experiment
Airplane dusting experiments					
			First generation		
Chlorinated camphene	10	9	+ 5	+13	−182
Benzene hexachloride (gamma isomer)	2	12	+ 3	−14	−112
Ryania	40	12	−11	− 7	+112
			Second generation		
Chlorinated camphene	10	8	−15	−22	−240
		6	−14	−18	+ 93
		8	+ 7	+ 4	+323
		8	− 2	− 7	+200
		5	+38	−31	+130
		19	+ 2	+ 4	− 67
		Average	−10	−12	+ 73
		15	+ 5	+ 7	−164
Benzene hexachloride (gamma isomer)	2	15	+ 6	0	−303
Ryania	40	13	+ 1	− 1	−110
Small-plot experiments in which insecticides were compared on second-generation borers with untreated checks					
Cryolite		32	75[3]	67[3]	+298
Chlorinated camphene	10	32	88[3]	20[3]	+321
Sulfur		32	49[3,4]	59[3,4]	−226

[1] Cryolite control estimated at 83 per cent on first-generation and 73 per cent on second-generation borers, which were the controls obtained on these generations in small-plot experiments in 1947.
[2] Cryolite control estimated at 50 per cent based on harvest time control in cryolite plots in previous years.
[3] Actual controls compared with untreated check plots.
[4] Increase.

years indicate that application of *Ryania* does not materially increase the yellow sugarcane aphid population.

Benzene hexachloride.—A benzene hexachloride dust containing 2 per cent of the gamma isomer was more effective than cryolite in controlling borers in summer-planted cane in 1945, but much less effective in such cane in 1946. In 1946 dusts containing 1 and 1.5 per cent of the gamma isomer gave fully as good control of first-generation borers as did cryolite. Against second-generation borers a dust containing 1.15 per cent of the gamma isomer was somewhat less effective than cryolite.

In 1947 benzene hexachloride dust containing 2 per cent of the gamma isomer was more effective than cryolite in controlling first-generation borers in two of four experiments (Table 1), the percentages of control for the four experiments averaging 81 for cryolite and 84 for benzene hexachloride. A dust containing 1 per cent of the gamma isomer gave poorer control than the 2 per cent in two experiments, averaging only 58 per cent control. Neither 2 nor 3 per cent gamma applied three times at 10-day intervals gave as good borer control as the 2 per cent applied four times at weekly intervals. Three and one-third pounds of wettable benzene hexachloride containing 6 per cent of the gamma isomer in 80 gallons of water per acre gave 97 per cent control of first-generation borers, whereas cryolite dust gave 90 per cent control. A dust containing 2 per cent of gamma gave slightly better control of third- and fourth-generation borers in summer-planted cane than

did cryolite dust and slightly lower control of second-generation borers.

In a large-acreage airplane dusting experiment on first-generation borers a benzene hexachloride dust containing 2 per cent of gamma gave somewhat better control than cryolite, but at harvest time the infestation in the benzene hexachloride plots was 28 per cent greater and the yield of sugar was 112 pounds per acre less than in the cryolite plots. In a similar experiment on second-generation borers benzene hexachloride dust containing 2 per cent of gamma gave a somewhat higher degree of control than cryolite, but the infestations were equal at harvest time and the cryolite plots outyielded the benzene hexachloride plots by 303 pounds of sugar per acre.

As in previous years, plots dusted with benzene hexachloride had a much lower yellow aphid infestation than cryolite plots, and about the same infestation as the chlorinated camphene plots. Field counts, however, indicated that there was a more rapid borer multiplication in large-acreage benzene hexachloride plots than in cryolite plots. Limited laboratory tests indicated that emergence of the borer egg parasite *Trichogramma minutum* Riley and parasitization of borer eggs were decreased by benzene hexachloride dust.

Chlorinated Camphene.—In 1946 a dust containing 10 per cent of chlorinated camphene gave better control than did cryolite of first-generation borers and also of third- and fourth-generation borers in summer-planted cane. A 5-per cent dust gave somewhat lower control than cryolite on the third and fourth generations. The number of yellow sugarcane aphids present following treatment with the 10-per cent dust for second-generation borer control was significantly smaller than in cryolite plots.

In 1947, 10-per cent chlorinated camphene dust gave better control than cryolite in two of four small-plot experiments on first-generation borers, with cryolite giving the best control in the other two tests (Table 1). The percentages of control for the four experiments averaged 87 for chlorinated camphene and 81 for cryolite. Seven-per cent chlorinated camphene dust gave poorer control than cryolite. Ten-per cent chlorinated camphene dust applied three times at 10-day intervals gave poorer control than cryolite applied the usual four times, but 15-per cent chlorinated camphene dust applied three times at 10-day intervals gave control about equal to that of cryolite. Four pounds of 25-per cent wettable chlorinated camphene in 80 gallons of water per acre gave somewhat better control than cryolite dust.

Ten-per cent chlorinated camphene dust gave definitely poorer control of third- and fourth-generation borers on summer-planted cane than cryolite, averaging only 47 per cent control when cryolite averaged 77 per cent control. Twenty per cent chlorinated camphene gave control about equal to that of cryolite under similar conditions.

On second-generation borers 10-per cent chlorinated camphene dust gave an average control of 51 per cent in three experiments in which cryolite gave an average control of 73 per cent.

In an airplane dusting experiment on borers of the first generation (Table 2) 10-per cent chlorinated camphene dust gave about the same initial and harvest time control as cryolite, but the yield of sugar was higher in the cryolite plots. In six airplane dusting experiments on second-generation borer control 10-per cent chlorinated camphene dust gave an average borer control of 14 per cent less than cryolite and an average of 24 per cent less control at harvest time. The chlorinated camphene plots, however, yielded an average of 73 pounds more sugar per acre than the cryolite plots. In small-plot experiments on second-generation borers which were weighed at harvest time, plots dusted with 10 per cent chlorinated camphene gave a yield of sugar equal to cryolite plots in spite of the poorer control obtained with that material.

As may be seen in table 3, there was a heavy reduction in yellow sugarcane aphids in plots dusted with 10-per cent chlorinated camphene as compared with cryolite plots in every one of the six experiments in which aphid population counts were made. There were from 4 to 33 times as many aphids in the cryolite as in the chlorinated camphene plots. There was also a heavy reduction in corn leaf aphids, *Aphis maidis* Fitch, and rusty plum aphids, *Hysteroneura setariae* (Thos., in plots dusted with 10-per cent chlori-

Table 3.—Effect of applications of various insecticidal dusts to control second-generation sugarcane borers on the populations of other insects in sugarcane fields.

Number of Cuts	Cryolite	Chlorinated Camphene, 10 Per Cent	Benzene Hexachloride, 2 Per Cent Gamma	*Ryania*, 40 Per Cent	Sulfur	Check, No Treatment
			Yellow sugar cane aphids per 100 leaves			
32[1]	475	39			62	71
8	1363	324				
5	7435	225				
6	2110	122				
9	155	27	48			
9	577	85	115			
6	267			118		
6	1893			1577		
			Corn leaf aphids per 25 Johnson grass plants (Sorghum halapense)			
5	652	283				
			Rusty plum aphid-infested sugarcane plants per 20			
24[1]	5.5	0.3				4.5
			Mealybug-infested sugarcane stalks per 20			
32[1]	13	4			4	6

[1] Small-plot experiments; other figures refer to number of cuts dusted by airplane.

nated camphene as compared with cryolite plots. These two aphids are vectors of sugarcane mosaic disease. The number of sugarcane mealybugs, *Pseudococcus boninsis* (Kuw.), was also smaller in chlorinated camphene plots than in cryolite plots.

RESULTS WITH OTHER CHEMICALS.—A dust containing 2 per cent of parathion gave only 5 per cent control and a dust containing 1 per cent of parathion gave practically no control of third-generation sugarcane borers when cryolite gave 18 per cent control. The 2-per cent dust gave a small increase in the borer infestation over untreated check plots in one experiment on third- and fourth-generation borers when cryolite gave 65 per cent control. In another experiment the 2-per cent dust gave 52 per cent control and a 1-per cent dust gave 20 per cent control when cryolite gave 89 per cent control. In limited laboratory tests parathion decreased *Trichogramma* parasite emergence and parasitization.

A dust containing 5 per cent of 3,4-dichlorobenzenesulfone *p*-nitroanilide gave only 23 per cent first-generation borer control.

As in past years, sulfur applications caused an increase in the borer infestation. The herbicide 2,4-D, which had caused increases in the borer infestation in 1946, apparently gave some slight decrease in the borer infestation in the absence of *Trichogramma*, but in the presence of heavy parasitism as at the time of second-generation borer injury it resulted in a 58 per cent increase in the infestation.

In previous years poor control of the borer has been obtained with 5 per cent chlordane, 10 per cent sabadilla, and a number of other compounds. Dusts containing high percentages of sodium fluosilicate have given good first-generation borer control but poor second-generation control and also have caused rather severe burning of sugarcane foliage.

SUMMARY.—*Ryania* and chlorinated camphene have continued to show promise as sugarcane borer insecticides and further intensive testing of these materials is desirable to determine their practical usefulness in borer control. Chlorinated camphene has also controlled the yellow sugarcane aphid, which often increases to damaging numbers following applications of cryolite. The possibility of an accelerated increase in the borer population following applications of benzene hexachloride makes this insecticide unpromising for sugarcane borer control. Parathion and 3,4-dichlorobenzenesulfone *p*-nitroanilide did not give satisfactory borer control at the strengths tested.

Improvement of Nozzles for Applying Concentrated Insecticides as Fine-Mist Sprays[1]

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The use of concentrated sprays (Lindquist *et al.* 1945) for the control of household insects places emphasis on the development of equipment to apply these concentrates. A capillary-tube sprayer described by Schroeder and Lindquist (1946) was an improvement in this field. obtain information of value in the further improvement of nozzles for applying concentrated insecticides as fine-mist sprays against house flies and mosquitoes. Equipment of equal effectiveness against both insects is considered essential, since they frequently are present together. In these

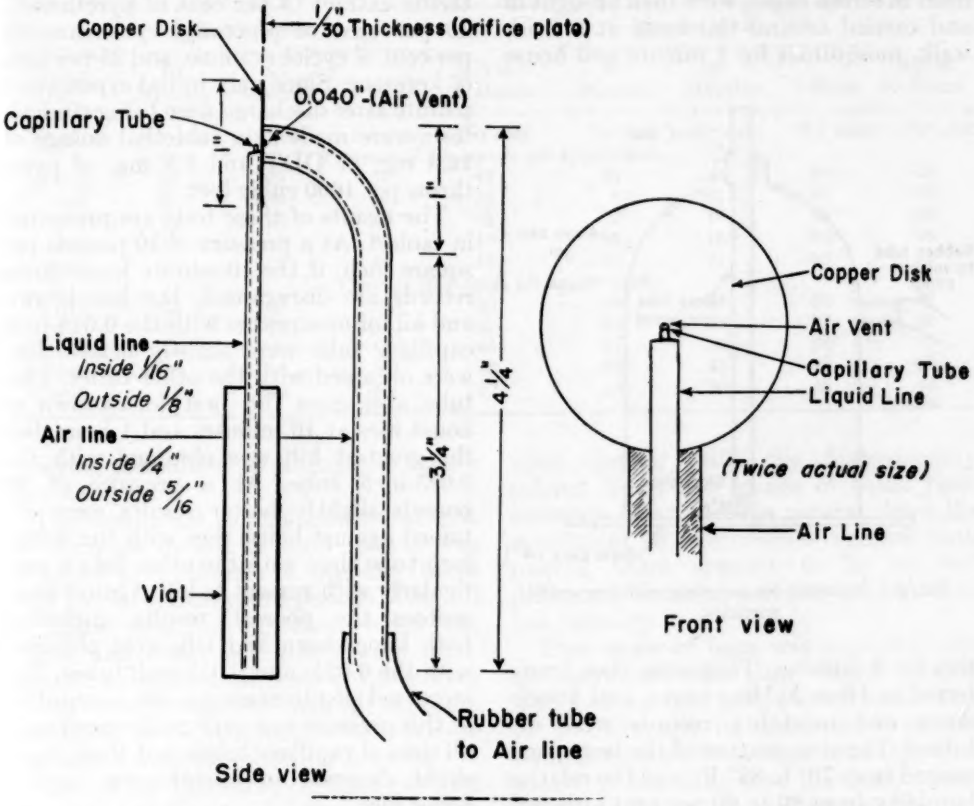

Fig. 1.—Side and front-view diagram of an experimental nozzle used to apply concentrated insecticides as fine-mist sprays.

Experiments have been conducted at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine to experiments such factors as size of the capillary tube and air vent, operating pressure, and viscosity of solvents were studied. The results reported here, although preliminary, may stimulate further investigations along the same lines.

Equipment and Methods.—Experimental nozzles incorporating the essential principles of those in the capillary-tube sprayer were constructed especially for

[1] This work was conducted under a transfer of funds, recommended by the Committee on Medical Research, from the Office of Scientific Research and Development to the Bureau of Entomology and Plant Quarantine.

[2] Geo. T. McCullough, Sergeant, AUS, assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides at Army Air Forces Center, Orlando, Fla., assisted in the project.

[3] The assistance of Douglass Burnett, Jr., and the helpful suggestions of H. A. Jones are gratefully acknowledged.

these investigations. A diagram of one of these nozzles is shown in figure 1. For comparative purposes nozzles with capillary tubes and air vents of different sizes were used.

The tests were conducted against the house fly, *Musca domestica* L., and the common malaria mosquito, *Anopheles quadrimaculatus* Say, in large rooms (7000 cu. ft.). A 16-inch electric fan was operated for a short time before and until 1 minute after the release of the spray to distribute the particles evenly throughout the room. The insects, which were confined in screen cages, were then brought in and carried around the room at a brisk walk, mosquitoes for 1 minute and house

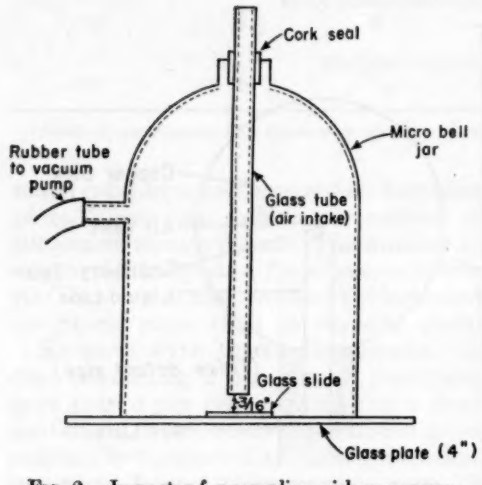

FIG. 2.—Impactor for sampling airborne spray particles.

flies for 2 minutes. They were then transferred to clean holding cages, and knockdown and mortality records were obtained. The temperature of the test rooms ranged from 70° to 82° F., and the relative humidity from 20 to 60 per cent although most of the tests were made at about 40 per cent humidity.

The approximate number and size of the airborne spray particles were determined in connection with some of these tests. For sampling the spray a device called an impactor, shown in figure 2, was used. When the vacuum pump was operated at the rate of approximately 55 liters per minute, spray droplets were drawn through the glass tube and impinged on the glass slide beneath. Samples were taken at a height of about 3 feet.

COMPARISON OF CAPILLARY TUBES OF DIFFERENT SIZES IN INITIAL-EXPOSURE STUDIES.—In the first tests capillary tubes of different sizes were compared at two spraying pressures. The diameters (i.d.) of the capillary tubes were 0.015, 0.025, 0.035, 0.045, and 0.055 inch. The diameter of the air vent in all cases was 0.04 inch. Pressures of 10 and 20 pounds per square inch were chosen because they are within the ordinary operational range of hand-spraying equipment. The spray formula consisted of 20 per cent of DDT, 15 per cent of a 20 per cent pyrethrum extract (3 per cent of pyrethrins), 20 per cent of piperonyl cyclonene, 20 per cent of cyclohexanone, and 25 per cent of kerosene. Since only initial exposures 1 minute after discharge were being studied, tests were made at a sublethal dosage of 12.8 mg. of DDT and 1.8 mg. of pyrethrins per 1000 cubic feet.

The results of these tests are presented in table 1. At a pressure of 10 pounds per square inch, if the 10-minute knockdown records are disregarded, the knockdown and kill of mosquitoes with the 0.015-inch capillary tube were slightly better than were obtained with the other tubes. This tube also gave the best knockdown of house flies at 10 minutes and 1 hour, but the greatest kill was obtained with the 0.025-inch tube. At a pressure of 20 pounds slightly better results were obtained against house flies with the 0.035-inch tube than with the other tubes, particularly with respect to kill. Against mosquitoes the poorest results, including both knockdown and kill, were obtained with the 0.035- and 0.055-inch tubes. The increased effectiveness against mosquitoes at this pressure was very pronounced with all sizes of capillary tubes, but there was a slight decrease in effectiveness against house flies.

SETTLING-RATE STUDIES.—Since a space spray is effective only as long as the particles remain suspended in the air, beiological studies were made to determine the settling rates of the sprays produced by different types of equipment or with different solvents. The insects were exposed 1, 15, 30, and 60 minutes after discharge of the spray. The test rooms were kept closed during the tests. The same spray formula was used but at a much higher dosage—100 mg. of DDT and 15 mg. of pyrethrins—than in those

tests in which only the initial exposure was considered.

EFFECT OF SIZE OF CAPILLARY TUBE.—In one series of tests nozzles with capillary tubes of different sizes were compared, both when the insects were exposed for the usual periods, 1 minute for mosquitoes and 2 minutes for house flies, and when they were exposed for longer periods. The 0.04-inch air vent and a spraying pressure of 10 pounds per square inch were used.

The results are summarized in table 2. An increase in kill of both insects was obtained with all sizes of capillary tubes with the longer exposure periods. The kill of house flies was greatest when the 0.015- and 0.025-inch tubes were used. Against mosquitoes all sizes of tubes were about equally effective with all exposure periods. Knock-down records were in close agreement with the mortality records.

EFFECT OF VISCOSITY OF SOLVENT AND SIZE OF AIR VENT.—Further tests were conducted to compare solvents of high and low viscosity when the sprays were applied at pressures of 10 and 20 pounds per square inch. For this purpose the low-viscosity solvents cyclohexanone and kerosene in the spray formula were replaced by benzyl benzoate, a high-viscosity solvent, and comparative tests were made with the two formulas. The nozzle with the 0.025-inch capillary tube and a 0.04-inch vent was used, since they had been found to be most effective against both house flies and mosquitoes.

The results of these tests are given in table 3. The best kill of house flies 15 minutes after spraying was obtained with the low-viscosity solution discharged at 20 pounds' pressure. At this pressure there was a pronounced increase in kill of mosquitoes at the 15- and 30-minute exposure intervals, when both solvents were used. The general effectiveness was somewhat greater with the high-viscosity solvent when the results of equal pressures are compared. In general, from the standpoint of effectiveness against both insects, there appears to be no real difference between solvents of high and low viscosity.

This series of tests was repeated with all conditions the same except that a 0.03-inch air vent was used. There was a general decrease in effectiveness against both insects at the longer intervals after spraying, but otherwise the results were similar to those with the larger vent.

SPRAY-PARTICLE DATA.—Data on spray particles obtained in connection with these tests are shown in table 4. With the 0.04-inch air vent there was little variation in particle size due to differences in viscosity and pressure. With both the high- and low-viscosity solutions the greater numbers of particles at the delayed exposure intervals were obtained at a pressure of 20 pounds. The largest particles and the greatest numbers settled out during the first 15 minutes after spray-

Table 1.—Effectiveness of sprays discharged at different pressures from nozzles having different-sized capillary tubes, when the insects were exposed immediately after the spraying.

Size of Capillary Tube (i.d.)	*Musca domestica*				*Anopheles quadrimaculatus*			
	Knock-Down in—			Kill in 24 Hours	Knock-Down in—			Kill in 24 Hours
	10 Minutes	30 Minutes	1 Hour		10 Minutes	30 Minutes	1 Hour	
Inch	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Pressure of 10 pounds per square inch								
0.015	55	69	57	47	16	53	60	65
.025	38	89	56	59	6	27	60	58
.035	26	55	33	51	7	16	38	45
.045	16	52	30	46	13	16	29	46
.055	18	51	34	43	22	21	40	52
Pressure 20 pounds per square inch								
.015	53	82	52	35	28	64	92	89
.025	26	43	35	27	23	55	87	92
.035	40	83	51	44	17	40	62	77
.045	34	46	39	33	25	48	91	93
.045	19	40	40	27	15	30	60	66

Table 2.—Effectiveness of sprays discharged at a pressure of 10 pounds per square inch from nozzles having different-sized capillary tubes when the insects were exposed at different intervals after spraying and for different exposure periods. The kill in all cases is after 24 hours.

Size of Capillary Tube (i.d.)	Interval Between Spraying and Exposure	*Musca domestica*			*Anopheles quadrimaculatus*		
		Kill After Exposure for 2 Minutes	Time of Longer Exposures	Kill	Kill After Exposure for 1 Minute	Time of Longer Exposures	Kill
Inch	*Minutes*	*Per Cent*	*Minutes*	*Per Cent*	*Per Cent*	*Minutes*	*Per Cent*
0.015	1	99	—	—	99.6	—	—
	15	59	4	71	97	2	99
	30	23	6	49	61	3	93
	60	11	8	17	7	4	32
.025	1	100	—	—	100	—	—
	15	38	4	55	87	2	96
	30	13	6	16	57	3	88
	60	5	8	19	11	4	46
.035	1	100	—	—	100	—	—
	15	14	4	12	62	2	82
	30	11	6	11	33	3	60
	60	4	8	6	28	4	38
.045	1	96	—	—	100	—	—
	15	3	4	7	86	2	94
	30	3	6	6	52	3	81
	60	3	8	1	15	4	58
.055	1	99	—	—	99.7	—	—
	15	20	4	33	65	2	93
	30	28	6	29	35	3	84
	60	12	8	8	9	4	14

Table 3.—Effectiveness of sprays containing low- and high-viscosity solvents when applied with a nozzle having a 0.025-inch capillary tube and a 0.04-inch air vent at different pressures when the insects were exposed at different intervals after spraying.

Pressure Pounds per Sq. Inch	Interval Between Spraying and Exposure in Minutes	*Musca domestica*				*Anopheles quadrimaculatus*			
		Per Cent Knock-Down in Minutes			Per Cent Kill in 24 Hours	Per Cent Knock-Down in Minutes			Per Cent Kill in 24 Hours
		10	30	60		10	30	60	
Low-viscosity solvents (cyclohexanone and kerosene)									
10	1	99.7	100	100	99	77	100	100	100
	15	2	6	5	23	48	79	97	85
	30	0	0	0	5	17	25	35	34
	60	0	0	0	3	8	9	9	16
20	1	99.6	100	100	99.6	90	100	100	100
	15	13	74	55	31	52	96	100	99
	30	1	2	1	6	28	68	85	74
	60	0	0	0	5	12	20	25	16
High-viscosity solvent (benzyl benzoate									
10	100	100	100	100	92	95	100	100	100
	15	7	12	3	19	64	92	95	93
	30	0	0	0	11	27	35	75	44
	60	0	0	0	3	11	14	14	3
20	1	100	100	100	98	96	100	100	100
	15	4	8	4	16	71	92	96	97
	30	0	0	0	5	28	51	78	99
	60	0	0	0	4	15	15	11	1

ing. This explains the abrupt drop in the knock-kown and kill of house flies obtained after the initial exposure period. This drop was not so pronounced in the case of mosquitoes, since the effective dosage against these insects is lower than that against house flies.

With the 0.03-inch air vent particle sizes were approximately the same as those obtained with the 0.04-inch air vent, but there was a greater decrease in the number of particles after the initial exposure period. This explains the reduced effectiveness against both insects.

COMPARISON OF DIFFERENT TYPES OF NOZZLES.—In a final series of tests an experimental nozzle with a 0.055-inch capillary tube and a 0.04-inch air vent was compared with a *DeVilbiss*-type paint sprayer and a *Brewer* electric sprayer, both of which produce a relatively large number of coarse droplets. The experimental and *DeVilbiss* nozzles were operated by an air compressor at 25 pounds per square inch, and the operating pressure of the electric sprayer was probably about the same. The regular spray formula containing cyclohexanone and kerosene as solvents was used.

The best knock-down and kill at all exposure intervals were obtained with the experimental nozzle (Table 5), and the Brewer sprayer was the least effective. At the initial exposure interval the results were not significantly greater with the experimental nozzle than with the *DeVilbiss*.

Data on spray particles obtained in connection with this series of tests are included in table 5. As in previous tests, the average particle size varied slightly between nozzles. However, fewer particles were produced by the *DeVilbiss* and Brewer nozzles, particularly at the later sampling periods. This explains why there was such a decrease in effectiveness

Table 4.—Spray-particle data obtained in connection with tests to compare the effectiveness of high- and low-viscosity solvents and 0.025-inch nozzles with different-sized air vents.

Pressure in Pounds per Sq. inch	Minutes After Spraying	Particles from—		Average Diameter of Microns	
		0.04-Inch Air Vent	0.03-Inch Air Vent	0.04-Inch Air Vent	0.05-Inch Air Vent
		Low-viscosity solvent			
10	1	208	251	4.1	3.7
	15	138	123	3	2.7
	30	135	63	2.8	2.4
	60	59	21	2.5	2.3
20	1	241	333	4	3.7
	15	200	185	3	2.6
	30	132	101	3.2	2.7
	60	83	34	2.6	2.4
		High-viscosity solvent			
10	1	270	292	3.6	4.1
	15	144	155	2.5	2.6
	30	78	74	2.6	2.5
	60	31	21	2.8	2.4
20	1	280	318	4.6	4
	15	345	236	2.6	3
	30	159	100	3	2.3
	60	97	37	2.3	2.4

Table 5.—Effectiveness of sprays produced by sprayers with different types of nozzles when the insects were exposed at different intervals after spraying, together with spray-particle data.

Minutes Between Spraying and Exposure	*Musca domestica* Per cent Knock-Down in Minutes			*Musca domestica* Per cent Kill in 24 Hours	*Anopheles quadrimaculatis* Per cent Knock-Down in Minutes			*Anopheles quadrimaculatis* Per cent Kill in 24 Hours	Particles Discharged	Average Diameter of Particles (Microns)
	10	30	60		10	30	60			
					Experimental nozzle (0.055 in.)					
1	100	100	100	92	92	100	100	100	211	4.4
15	2	17	6	19	57	82	99	85	157	3.3
30	0	0	0	8	29	58	60	50	82	2.6
60	1	0	0	7	14	12	12	9	42	2.7
					De Vilbiss sprayer (0.043 in.)					
1	100	100	100	89	91	99.6	100	99.6	174	4.7
15	0	0	0	1	48	63	90	77	126	2.7
30	0	0	0	8	14	19	26	7	58	2.5
60	0	0	0	1	4	5	5	5	22	2.6
					Brewer sprayer					
1	64	76	71	46	29	87	95	87	93	3.7
15	0	0	0	3	12	12	15	10	50	3.0
30	0	0	0	1	7	8	8	4	29	2.8
60	0	0	0	2	0	4	2	5	10	2.8

against both mosquitoes and house flies between the initial and the delayed exposure intervals with these nozzles.

DISCUSSION.—The data indicate that the best results against both house flies and mosquitoes may be obtained with a sprayer having a nozzle with a capillary tube between 0.015 and 0.025 inch in diameter (i.d.), and that further progress will depend upon some radical changes in principles or design. There is some evidence that a larger air vent may increase the effectiveness of the equipment, but further tests are needed to establish this point and to determine the most satisfactory size.

A consideration of the data as a whole leads to the conclusion that, with the insecticides and concentrations used, the size and number of spray particles are more important in controlling house flies than mosquitoes. Burdette (1938) has shown that with light oils maximum toxicity to honeybees requires a certain optimum concentration of particles between 1 and 10 microns in diameter. If this principle holds for other insects, it appears possible that the range must be narrower for house flies than for mosquitoes, although under practical conditions longer exposures might tend to equalize this factor.

One method of increasing the effectiveness of concentrated sprays against both insects would be to increase the percentage of droplets having a diameter between 1 and 10 microns by increasing the pressure. Reducing the number of larger particles would also tend to decrease the settling rate. However, Burdette also shows that higher pressures permit a greater volume of the material to be atomized into particle sizes below 1 micron, with a consequent loss of effectiveness. Data in this paper tend to substantiate this conclusion with respect to house flies. It is therefore apparent that both extremities of particle size must be lowered.

SUMMARY.—Experiments were conducted to develop improved nozzles for applying concentrated insecticides as fine-mist sprays against the house fly, *Musca domestica* L. and the common malaria mosquito, *Anopheles quadrimaculatus* Say. A spray containing 20 per cent of DDT, 15 per cent of a pyrethrum extract (3 per cent of pyrethrins), 20 per cent of piperonyl cyclonene, 20 per cent of cyclohexanone, and 25 per cent of kerosene was used. Such factors as size of siphon tube and air vent, operating pressure, and viscosity of solvents were studied.

The data indicate that the best results against both insects may be obtained with a nozzle having a capillary tube between 0.015 and 0.025 inch (i.d.). There is some evidence that the efficiency of the equipment also increases with the size of the air vent. In general, spray formulas containing solvents of high and low viscosity appear to be equally effective. There is a greater decrease in the number of particles than in their size with increasing intervals after discharge. Under the conditions of these tests the size and number of spray particles are more important in controlling house flies than mosquitoes. Apparently house flies require a narrower range of particle size than mosquitoes, although under practical conditions longer exposures might tend to equalize this factor.

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Melanoplus occidentalis occidentalis a Range Species of Grasshopper in Nevada

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The range grasshopper *Melanoplus occidentalis occidentalis* (Thomas) is present throughout much of the arid region of the central mountain states of the west, its native habitat. All known literature on this species lists it as solitary in habit. In Nevada, for the past 10 or more years, this species has deviated from the solitary existence, developed migratory habits and has become of economic importance.

The first recorded infestation of this grasshopper in Nevada was during the summer of 1939.

Mr. Hamilton Ott, a rancher in Big Smoky Valley, Nye County, requested that an investigation be made of the presence of a band of grasshoppers that he had been unable to control with bran and sodium arsenite bait (adults).

Mr. C. W. Jensen, Assistant State Leader, Grasshopper Control, was sent to Smoky Valley to survey the infestation. Mr. Jensen recommended extensive control measures and tentatively identified the species as *Melanoplus mexicanus*. Later the species was identified as *Melanoplus occidentalis occidentalis* (Thomas), by the Division of Insect Investigation, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

HISTORY.—Prior to 1939 the range grasshopper *Melanoplus occidentalis occidentalis* (Thomas) was not known to exist in the state of Nevada. Inquiry by Mr. G. M. Shogren, State Supervisor, Grasshopper Control in Nevada, concerning past infestations produced no reliable information. Local ranchers seemed to remember a heavy grasshopper infestation on the range about 30 years earlier. Indians reported that some 60 to 70 years ago a heavy range infestation occurred for two summers and did much damage, causing the deer to desert the range.

In July, 1938, a flight of grasshoppers, presumably *Melanoplus occidentalis*, settled over the buildings and fields of the Turner Ranch in Big Smoky Valley. The next morning the grasshoppers took wing again into the nearby hills and were not observed further. Later in the same summer a flight of grasshoppers appeared near Wall Canyon, a mile and a half south of the H. Ott Ranch. It is assumed that heavy egg deposition took place in this area, for in the spring of 1939 nymphs were first observed here. The flights that appeared at the Turner Ranch and at Walls Canyon are believed to be the same as they are separated by only 8 to 9 miles, and only one band of grasshoppers was present in Big Smoky Valley in 1938.

DESCRIPTION OF SPECIES.—*Melanoplus occidentalis occidentalis* (Thomas) is a long-winged, early maturing grasshopper. The males average 25 mm in length and females 30 to 32 mm. It is a reddish-brown species with light blue tibiae, the tegmina having two rows of small dark brown spots. The wings in flight seem transparent, with a decided blue cast. When at rest the wings are found to extend beyond the abdomen one-fourth inch or more.

LIFE HISTORY.—The eggs hatch about April 1, the young nymphs are very active and begin to migrate during the early instars. Growth is very rapid, and by the end of the third week in May practically all are adults. Copulation begins immediately and is followed by oviposition in 2 to 3 weeks. Egg deposition continues until the latter part of July at which time very few surviving adults can be found; this gives a life-span of about 4 months.

FEEDING HABITS.—Most feeding takes place during the morning hours at temperatures between 68° and 85° F., but feeding has been observed at temperatures of 50° and 92° F. The hoppers roost at night in sagebrush, rabbit brush, salt bush and similar vegetation; and as the temperature approaches 60° F., they start moving about and begin to feed. Being a range species of grasshopper they have a preference for range vegetation. Species of *Artemisia, Chrysothamnus, Purshia, Lupinus, Astragalus, Carex, Poa, Bromus, Rumex, Balsamorhiza, Eurotia, Oryzopsis* and *Erodium* are plants suffering the heaviest damage.

The damage to the plants listed is produced in two ways; defoliation, which is often total, the entire leaf being destroyed leaving the plant in a naked state, and

decortication of young stems down to, and including in some cases, the cambium layer. This type of damage has resulted in the death of many plants. In addition to the destruction of mature plants many annual and perennial seedlings are destroyed during the early spring.

The extent to which these range grasshoppers will destroy cultivated crops is unknown. To date they have not invaded grain, have produced some damage in alfalfa and sweet clover, and have completely destroyed graden crops such as potatoes, onions, corn, lettuce, beets and radish.

During the heat of the day, the adult grasshoppers will often rest in the shade of or climb into the bush. It is during this period that most of the decortication takes place, presumably to obtain moisture from the plant. The epidermis is stripped from young stems and damage to the cambium later follows.

During tests on adult hoppers with two insecticides, DDT and benzene hexachloride, cannabalism was observed. Grasshoppers migrating into the treated area immediately attacked the dead and dying, devouring all but the legs and head.

MIGRATION.—Migration by crawling occurs during all stages of development including adults. In the earlier instars the migration is an alternating crawling and resting. In the early adult stage the migration may be a combination of crawling, short flight and resting periods; while later it may be of the short flight, long high flight combination. During the crawling migration one is impressed with the military-like precision of the movement. A band of hoppers observed under these conditions was found to be composed of innumerable small concentrations 50 to 100 feet in diameter. Each concentration seemed to act independently of the other nearby concentrations, though the band as a whole migrated through the movement of its individual concentrations. A concentration of grasshoppers would be at rest, then all of a sudden the entire concentration would move forward as a body, stop, and rest with all the grasshoppers facing in the same direction.

In the early adult stage, when capable of flight, the entire concentration may move forward as described above, then take flight for a distance of 10 to 30 yards, alight and rest. The next movement may be by crawling or flight but in all instances the entire concentration moves as one individual.

During movement by short flight, but no crawling migration, the grasshoppers act as individuals, taking flight for short distances, resting and again taking flight. This individual movement produces a rolling effect by the band as a whole.

FLIGHT.—The flight migrations are of two types, the low short flight as described under migration and the long high flight. The flights are generally cross-wind to the prevailing wind, which is westerly in this region, but is influenced by local cross-currents produced by the terrain. The flight migrations occur during June and continue into July, passing through three stages, short flight, long flight and returning to short flight or a combination of the two.

Temperature and wind velocity are two factors influencing flight migrations. As a rule in the morning after it has warmed up, when the air temperature has reached 80° F. and the morning feeding is over, the grasshoppers begin to rise and soar. At first a few will rise, soar for awhile, and settle back to earth. Gradually more and more rise until the air is full of soaring grasshoppers. This soaring takes place when there is a movement of air but if the wind is in excess of 15 miles per hour the grasshoppers remain on the ground, or, if in flight when the air movement reaches 15 miles per hour they will settle to earth. The movement is in a definite direction with the flight varying from a few hundred feet up to several miles, a flight of 15 miles in one day was recorded. During the long flight the grasshoppers will rise as high as the eye can observe when looking toward the sun.

SPREAD.—From the first observations made in 1939 on the original infestation which covered an area approximately 2 miles by 3 miles in Big Smoky Valley, Nye County, the infestation has spread and moved in a northwest direction. A survey conducted during the summer of 1947 in northern Washoe and northwestern Pershing and Humboldt counties, the present infested area, produced known egg beds of approximately 155,000 acres. As this was the first survey conducted in a period of 4 years there are undoubtedly many unknown egg beds in the area.

The general direction of migration dur-

ing the years 1939 to 1947, was north from the original infestation in Nye County, through Eureka, Lander and eastern edges of Churchill and Pershing Counties into Elko and Humboldt Counties, crossing Highway U. S. 40 from Dunphy, Nevada on the east to Oreana, on the west. The movement was then west and northwest to the present infested area which extends into Oregon on the north and California on the west. There are no known infestations south or east of Highway U. S. 40.

COPULATION.—First mating takes place in late May and continues until the grasshopper population disappears in late July.

Mating usually takes place during the entire day. It begins when the air temperature reaches near 75° F.; or if the weather is quite warm it may end around noon. Highest air temperature at which mating was observed was 92° F.

OVIPOSITION.—Oviposition commences around the 1st of June and continues until late in July (after August 1, few adults are found). Egg laying begins around 8:30 A.M. when the air temperature approaches 80° F. and continues until around 12:00 noon when the temperature has usually reached the vicinity of 92° F. Rarely is egg laying observed after 1:30 P.M. Egg pods are approximately 3 to 4 mm in diameter and range from 30 to 45 mm in length. The eggs themselves average 5 mm in length, they are slightly curved and have a pearl grey color. The number of eggs per pod ranges from 14 to 25, 20 eggs being the average number during June laying. During the first part of July, from 13 to 19 per pod were found, an average of 16 per pod. Whether this is a difference between the first and second ovipositions is not known.

Egg beds are fairly well defined and in most cases are concentrated. The number of pods found per square foot varies from fewer than one to as high as 285. All egg beds observed were on gravelly and rocky soil. The tops of knolls, low hills or alluvial fans with southern or western exposures and good drainage were the chosen sites. The egg bed is usually concentrated in two ways; first the concentration in a given area and second, smaller concentrations within this concentration. The smaller concentration may be as small as a few square yards or as large as several square rods.

CONTROL.—During the summer of 1939 good control was had with the use of arsenic poison bait. Kills averaged 95 to 98 per cent. Since that time good kills have been made with the use of sodium fluosiilcate and bran bait during the early nymphal stages.

Attempts to control the adult grasshopper by the use of poison bait has met with failure, due, in part, to the migratory habit of the adult. Economic control is therefore confined to the instars when using poison bait. Preliminary test of some of the new insecticides on adults gave fair kills. From observations made during the tests it is believed that the kills were produced by the contact action of the insecticides rather than by their action as stomach poisons.

A control program is planned for the year 1948 using sodium fluosilicate, bran bait, and one of the new insecticides as a spray during the instar period.[1]

[1] NOTE: Information for this report was taken from notes of G. M. Shogren, Nevada State Department of Agriculture (killed in action, U. S. Army) and C. C. Wilson, (deceased, 1948) United States Department of Agriculture, Bureau of Entomology and Plant Quarantine. Information gained from these notes was confirmed by the writer and W. B. Mabee, U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

Tests of Insecticides, Including DDT, Against the Corn Earworm and the Fall Armyworm in Corn

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The experiments reported herein were conducted in Illinois, Mississippi, and Arkansas during 1944 through 1947 for the purpose of testing some of the newer insecticides, especially DDT, and different methods of applying them for the control of the corn earworm, *Heliothis armigera* (Hbn.), in market and canning sweet corn and in dent corn grown for seed. Data were also obtained during 1945 and 1946 on the effectiveness of these insecticides and methods in controlling the fall armyworm, *Laphygma frugiperda* (A. and S.), in sweet corn. Some of the data presented have already been reported (Blanchard *et al.* 1945 and 1946), but are included herein for consideration along with more recent information of value.

Sixteen insecticides were used in the tests. A summary of the insecticides and the forms in which they were tested is given in table 1.

METHODS.—Most of the data presented are based on randomized field-plot treatments with three to five replications of each treatment. In some preliminary experiments only a single plot was treated with each insecticide. When preliminary experiments indicated that any particular insecticide was promising, one or more additional tests with randomized and replicated plots were performed. Individual plots contained 8 to 25 ears.

The oil solutions were applied either with a small hand injector or as a fine spray with a paint spray gun or hand

Table 1.—Insecticides and forms in which they were tested for control of the corn earworm and fall Armyworm on sweet and dent corn. Illinois, Mississippi, and Arkansas—1944 through 1947.

INSECTICIDE	TYPE OF MIXTURE	CONCENTRATION (PER CENT)[1]	SWEET OR DENT CORN
DDT			
Technical grade	Oil solution	0.125 to 9	Both
	Emulsion	1 to 2	Both
	Dust	1 to 9	Both
Water-dispersible, 50 to 90 per cent of DDT	Emulsion	0.5 to 2	Sweet
	Emulsion	0.25 to 2	Sweet
	Suspension	1 to 2	Both
Dichlorodiphenyltricholorethane	Emulsion	1	Both
Methoxychlor	Emulsion	1 to 2	Sweet
	Dust	5	Sweet
Benzene hexachloride, 10 per cent gamma	Oil solution	0.5 to 2	Both
Benzene hexachloride, technical	Dust	1 to 2	Both
Chlordan	Emulsion	1 to 2	Sweet
Chlorinated camphene, 67 to 69 per cent chlorine	Emulsion	1 to 2	Sweet
	Dust	5	Sweet
Pyrethrins	Oil solution	0.2	Both
	Emulsion	0.2	Sweet
	Dust	0.2	Sweet
Piperonyl butoxide 1 part plus pyrethrins 1 part by weight	Oil solution	0.2	Sweet
	Emulsion	0.2	Sweet
Piperonyl cyclonene 1 part plus pyrethrins 1 part by weight	Emulsion	0.2	Sweet
Dichloroethyl ether	Oil solution	2	Both
Ethylene dichloride	Oil solution	2	Dent
Styrene dibromide	Oil solution	1 to 3	Both
Sabadilla	Dust	2 to 20	Dent
Ryania	Dust	50	Sweet
Parathion	Suspension	0.5 to 1	Sweet
	Emulsion	1	Both

[1] Approximate—in case of insecticides which are solids, the figures given represent grams per 100 ml. of total liquid. See table 2.

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atomizer. Most of the emulsions and suspensions were applied with the paint spray gun or atomizer, but some were applied with a conventional garden sprayer which provided a relatively coarse spray. In Mississippi some emulsions were also injected. The dusts were applied with knapsack or plunger-type dusters.

The amount of liquid applied ranged from 0.33 ml. to 9.4 ml. per ear. The dusts were applied heavily enough to cover the silks thoroughly. The concentration of DDT ranged from 0.125 to 9 gm. per 100 ml. of liquid, but the concentrations of most of the insecticides ranged from 0.5 to 2 gm. or ml., depending upon whether the insecticide was liquid or solid. Technical DDT was used in making the oil solutions. A dispersible form containing 90 per cent of DDT, supplied by the Division of Insecticide Investigations, was used in making up most of the emulsions and suspensions. A few commercial dispersible types containing 40 to 50 percent of DDT were compared with the 90 per cent material.

The proportion of oil used in the emulsions ranged from 1 to 30 per cent. Most of the mixtures were made by adding the emulsifier to the oil and making a paste with the DDT. The water was stirred in slowly and then the mixture was stirred rapidly in an electric mixer until a homogeneous, slow-breaking emulsion was formed. Equally good mixtures can be made by mixing the emulsifier with the oil, stirring in the DDT, and then adding this mixture directly to the water in the mixer. If the insecticide is to be used in a sprayer with an agitator, the latter method should be used; otherwise, the liquid may become too thick for spraying. No attempts were made to prepare a stock emulsion for later dilution in the field. A number of different emulsifiers were used.

The time of application ranged from 1 to 10 days after silk emergence. In some cases a single application was compared with two applications of the same material applied 1 day apart. In most of the tests on dent corn carried out in Mississippi, the silking dates of the individual ears were determined and treatments made on an exact schedule. No exact schedule was carried out in the Illinois and Arkansas tests. The time of emergence of first silks was determined, however, and any ears with silks obviously more or less advanced than the average were marked for discard by removing the tassels from the plants at the time treatments were made. The effects of treatments on ears with immature silks, *i.e.*, unfertilized or very recently fertilized silks, were studied in Illinois and Arkansas on sweet corn and in Mississippi on field corn grown for seed. Comparisons were made with treatments on ears which were known definitely to have been fertilized. In sweet corn these observations were based on the physical condition of the silks rather than on the length of time after emergence. Silks judged to be immature were undoubtedly less than 2 days old and many had not completely emerged. The wilted or brown silks emerged from 4 to 8 days prior to treatment. In any one set of experiments, attempts were made to select ears of identical maturity in each of the individual plots.

At least one untreated check plot was left in each replication. Since a mineral-oil solution of DDT applied by injection gave almost perfect control, it was also included as a standard in most tests. In a few of the tests, oil alone, either white mineral oil or highly refined kerosene, was applied by injection as a check. The viscosities of the oils as given in this paper were determined at 100° F.

RESULTS.—The following factors were taken into account in judging the performance of the several insecticides:

1. Effectiveness of control of the earworm and fall armyworm as shown by percentages of undamaged ears and percentages of sweet corn ears on which the damage did not extend more than 0.5 inch from the tip. The numbers of living larvae present per ear in each treatment at harvest time were also recorded.

2. Failure of kernels to fill, rotting of the ear tips, and burning of the husks and plants.

3. DDT residues remaining on the kernels, cobs, and husks at harvest time following the most promising treatments with this insecticide.

4. Effect of DDT treatments on germination of dent corn seed.

5. Taste, odor, and effects on the operator.

The data concerning the control attained with the various treatments on both sweet and dent corn were tabulated

separately according to kind of corn and stage of maturity when treated. In this paper only those treatments which gave excellent results in all or most of the tests are presented. However, all the data obtained, as well as those shown in table 2, were taken into consideration.

CONTROL OF EARWORM AND FALL ARMYWORM.—DDT, technical benzene hexachloride, and gamma benzene hexachloride dissolved in mineral oil or deodorized kerosene gave perfect or nearly perfect control of both the earworm and the armyworm when injected into the silk channels. A highly refined white mineral oil (80 to 90 sec. Saybolt viscosity) containing only 0.2 gm. of DDT per 100 ml. of oil was very effective at a dosage of 0.75 ml. per ear. DDT at as low as 0.25 gm. and technical benzene hexachloride at 1-gm. strength in white mineral oils (80 to 125 sec. Saybolt viscosity) were very effective at a dosage of 0.33 ml. per ear. The benzene hexachloride was not tried at a concentration of less than 1 gm. per 100 ml. of oil.

The white mineral oil (80 to 90 sec. Saybolt viscosity) containing 1 or 2 gm. of technical DDT to 100 ml. of oil gave nearly perfect control of both insects when applied to the ears as an atomized spray at 0.5 and 1.0 ml. per ear. Pyrethrins at

Table 2.—Insecticide formulations and methods of application which gave consistently good control of the earworm and fall Armyworm in sweet corn. Illinois, Arkansas, and Mississippi, 1944 through 1947.

FORMULATION	EFFECTIVE RATES PER EAR	TESTS	UNDAMAGED EARS, AVERAGE	EAR TIPS DAMAGED MORE THAN ¼ INCH	LARVAE PER EAR, AVERAGE		TIP DAMAGE IN EXCESS OF THAT IN CHECKS, AVERAGE
					Earworm	Fall Armyworm	
	Milliliters	*Number*	*Per cent*	*Per cent*	*Number*	*Number*	*Inches*
Insecticides Applied by Injection							
DDT, technical: 0.25 to 2 gm., to 100 ml. with white mineral oil (80 to 125 sec. Saybolt) or motor oil (SAE 20 to 30)	0.33	6	94.1	1.3	0	0	Slight to 0.56
0.2 gm., to 100 ml. with white mineral oil (80 to 90 sec. Saybolt) or deodorized kerosene	0.75	2	97.3	0	—	—	None[1]
Benzene hexachloride, technical: 1 g., to 100 ml. with mineral oil (80 to 90 sec. Saybolt)	0.33	2	97.5	0	0	0	1.15[2]
Gamma benzene hexachloride, 0.5 to 2 gm. to 100 ml. with deodorized kerosene	.75	3	90.5	—	—	—	—
Insecticides Applied by Atomization							
DDT, technical: 2 gm., to 100 ml. with white mineral oil (80 to 90 sec. Saybolt)	1	9	93.7	0	0	0	.38
	.5	1	100	0	0	—	.43
2 gm., to 100 ml. with deoderized kerosene	.75	4	84.2	—	—	—	0[3]
1 gm., to 100 ml. with white mineral oil (85 to 90 sec. Saybolt)	1	1	83	0	0	—	Less than checks
DDT, dispersible (90 per cent): 2 gm. plus 1 ml. of Emulsifier,[4] 50 ml. of white mineral oil (80 to 90 sec. Saybolt) with water to make 100 ml.	1.0	1	67.3[5]	0	0	—	Less than checks
2 gm. plus 0.5 ml. of Emulsifier, 20 ml. of white mineral oil (80 to 80 sec. Saybolt) with water to make 100 ml.	4	3	84	4.7	0.15	0	.33
	3	1	52.5[6]	22.1	.33	—	.09
	2	1	84.6	0	.23[7]	—	.27
DDT, dispersible (50 per cent): 2 gm. plus 0.5 ml. of Emulsifier, 20 ml. of white mineral oil (85 to 95 sec. Saybolt) with water to make 100 ml.	3	2	68.7	5	.16	—	.20
	Unknown	1	100	0	0	—	.52
Chlordan, technical: 1 ml. plus 0.5 ml. of Emulsifier, 20 ml. of white mineral oil (85 to 95 sec. Saybolt) with water to make 100 ml.	3	3	65.3	11.7	.12	—	.42
Untreated Checks							
No treatment	—	16	6.5	77.2	1.21	.7	—

[1] Treatment applied after pollination had been completed.
[2] Corn inedible due to odor or flavor, and kernels up to 3 inches from ear tip failed to develop on some ears.
[3] Dent corn.
[4] A phthalic glyceryl alkyd resin (*Triton B1956*).
[5] Some slight feeding prior to application of insecticides.
[6] Corn affected by drouth; loose husk, poor ear development.
[7] Larvae very small, just entering ears 19 days after treatment.

0.2 per cent strength in mineral oil applied at the same rates resulted in very little control of the earworm. Deodorized kerosene containing 0.2 to 2 gm. of DDT per 100 ml., atomized at 0.5 to 0.75 ml. per ear, gave good control in dent corn, with the best results from the 2-gm. strength, but was somewhat less effective than mineral oil or kerosene containing 0.2 to 2 gm. of DDT per 100 ml. injected at 0.33 to 0.75 ml. per ear. Mineral-oil solutions of DDT appeared to give better results than kerosene solutions where the materials were atomized.

An emulsion containing 2 gm. of dispersible DDT and 30 ml. of white mineral oil (85 to 95 sec. Saybolt viscosity) per 100 ml. of liquid atomized at 1 ml. per ear gave perfect control of the earworm in one test in 1945. This is the only emulsion containing such a high percentage of oil that was used in any of the tests. An emulsion containing 2 gm. of dispersible DDT and 20 ml. of mineral oil per 100 ml. of liquid gave excellent results in four out of five tests where it was applied by atomization at 2 and 4 ml. per ear. In one test where 3 ml. per ear of this emulsion was applied, only fair control was secured. Corn treated in this test had loose husks and poor ears as a result of drouth. This same emulsion, but with 1 ml. of chlordan per 100 ml. of liquid substituted for the DDT, gave fairly good control in three tests when atomized at 3 ml. per ear. Several other insecticides were substituted for DDT in this emulsion formula in 1947, but the results secured with them were not encouraging. In general all the mixtures were somewhat slower in action and more larvae penetrated and slightly damaged the ears when the insecticides were applied by atomization than when they were injected. The formulations which gave good to excellent control and the methods by which they were applied are given in table 2.

Emulsions containing 10 ml. of white mineral oil (85 to 95 sec. Saybolt viscosity) and 2 gm. of DDT per 100 ml. of liquid applied by atomization were highly effective in some cases and only moderately so in others in 1945 and 1946 in the same plots were dispersions containing 20 ml. of the oil per 100 ml. of liquid gave very good to excellent results. Similar emulsions containing chlordan, piperonyl butoxide plus pyrethrins, or chlorinated camphene gave somewhat less control than those containing DDT.

Emulsions containing only 5 per cent of oil and 2 gm. of DDT per 100 ml. of liquid were still less reliable than those containing 10 per cent of oil, whereas those with 2.5 per cent of oil or less were, in general, ineffective. Two exceptions to this occurred, but in both cases application of the insecticide was followed by rainfall which was thought to have aided penetration of the insecticide into the ear tips. The lowered effectiveness of formulas containing relatively small percentage of oil appears to be due to lack of penetration of the ears. Some penetrant other than oil might perhaps be used successfully. In 1947 a sodium sulfate of a higher secondary alcohol added as a penetrant to an emulsion containing 5 per cent of oil seemed to increase greatly the control secured but caused severe burning of the plants at the strength used.

Kerosene alone applied by injection gave no control of the earworm in the few trials made of it. Injection of white mineral oil alone gave some control in corn varieties with fairly tight husks, but poor control in loose-husked varieties. In only one case where oil was applied alone was the control comparable to the better formulations containing DDT applied either by injection or atomization.

Oil solutions or emulsions containing insecticides have given a high degree of control under certain conditions when as little as 0.5 ml. per ear was applied by atomization. The minimum effective dosage was not determined, but from a practical standpoint dosages considerably above 0.5 ml. per ear would usually be required where the material is atomized. The actual amounts necessary probably depend upon formulation, population level, time and method of application, droplet size, and other factors. Emulsions containing 20 per cent of mineral oil, atomized as a relatively fine mist directly at the silks at a rate of 2 to 4 ml. per ear, gave excellent control under good growth conditions. Equipment capable of breaking up the spray into a still finer mist then that employed might be more efficient.

Ears were less damaged by the earworm when they were treated while the silks were fresh than when they were treated

after the silks had been exposed for 6 to 8 days, whether the insecticides were applied by injection or atomization. As mentioned earlier, however, all or nearly all the earworms were killed with the better formulations, whether the treatments were applied by injection or atomization. On the other hand, some formulations which gave perfect control of the fall armyworm when applied to silks 6 to 8 days old did not give such good control when applied to silks less than 3 days old. DDT in mineral-oil solution and in emulsions having not less than 20 per cent of oil gave perfect control of the fall armyworm, however, regardless of when the materials were applied. Reduction in oil content below 20 per cent tended to lower the degree of control. Less control, regardless of the insecticide mixture used, was secured in corn varieties with short loose husks than in those with husks sufficiently long and tight to reduce the rapidity of penetration by the larvae into the ears.

EFFECTS OF FORMULATIONS ON FILLING OF EARS.—Where undiluted oils were used as the carriers of insecticides, the tip kernels on the ears of sweet corn and inbred lines of dent corn failed to fill. This tip loss was greater in ears treated when silks were less than 3 days old then in older ears. In Illinois, undiluted oils caused greater tip loss on ears of both kinds of corn when injected at 0.5 ml. or more per ear than when applied at the same or higher rates by atomization. Emulsions containing DDT and as much as 30 per cent of oil caused no, or only slight, reduction in filling of the ear tip kernels even when applied by atomization to very immature silks.

Benzene hexachloride was the only insecticide that reduced ear filling. There was considerably more loss of tip kernels in hybrid field corn and sweet corn where white mineral oil or kerosene containing benzene hexachloride was used than where the same dosages of these oils alone or containing one of the other insecticides were used. In Illinois motor oil (SAE 30) applied by injection caused less tip loss in dent corn inbreds than white oils of lighter grades (80 to 125 sec. Saybolt viscosity) applied in the same manner. It is thought that the oil of lower viscosity caused greater damage by penetrating more deeply into the ears. Emulsions or suspensions containing water should not be applied by injection, as they sometimes cause the tips of the ears to rot when so applied.

BURNING AND RESIDUES.—Formulations containing the technical grades of the insecticides dissolved in auxiliary solvents caused more plant damage than those containing water-dispersible preparations of the insecticides in suspensions or emulsions. Concentrates containing 25 per cent of xylene, 25 per cent of methylated naphthalene, or 18 per cent of a proprietary aromatic petroleum distillate (enough to permit the dissolving of 9 gm. of DDT per 100 ml. in the complete formulation) caused severe burning when applied either by injection or atomization. Formulations with 1 to 2 gm. of DDT per 100 ml. and 2.5 per cent of xylene or 2 per cent of cyclohexanone also caused severe burning when applied by atomization.

The dispersible forms of the insecticides, applied in water suspensions without oil, left a whitish residue on the outer husks which would lessen the value of unhusked market sweet corn. No residue occurred where 10 per cent or more of oil was used in emulsions made with dispersible powders containing 50 to 90 per cent of DDT. Some slight yellowing of the husks occurred where solutions or emulsions with a high oil content were applied at high dosages, but emulsions containing dispersible forms of the insecticides applied at dosages of not more than 5 ml. per ear had no serious effect on the appearance of the ears.

A total of 22 samples of sweet corn ears were taken at time of harvest as green corn, from plots treated with the more effective mixtures containing DDT, for chemical analysis. The DDT residues found in these samples are given in table 3. The one sample containing benzene hexachloride represents the only attempt made to determine the residue of any insecticide other than DDT. No more than 1.52 parts per million (p.p.m.) were found on the kernels and 2.7 p.p.m. on the cobs in any of the samples, whether the material was applied by injection or atomization. Also, only 0.47 and 4.7 p.p.m. were found on the silks and husks of the two samples which received dosages of 0.5 and 0.33 ml. per ear, respectively, by injection. However, exclusive of the impractical emulsion containing 25 per cent of xylene and 9 per cent of DDT, the DDT

Table 3.—DDT residues on a green weight basis on kernels, husks and silks, and cobs of sweet corn treated by different methods with DDT insecticides.[1]

Formulation	Dosage per Ear	Kernels		Silks and Husks, Chlorine Method	Cobs, Chlorine Method
		Chlorine Method	Colorimetric Method		
	Milliliters	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
Insecticides Applied by Atomization					
DDT, technical:					
2 gm., to 100 ml. with white mineral oil (80 to 90 sec. Saybolt)	1	0.07	—	18.9[2]	—
	1	0.5	—	69[2]	—
2 gm. plus 2.4 ml. of xylene, 0.5 ml. emulsifier[3] and water to make 100 ml.	1	0.2	—	228	—
9 gm. plus 1 ml. emulsifier,[3] 25 ml. of xylene, and water to make 100 ml.	1	0.7	—	984	—
DDT, dispersible powder, 2 gm. plus:					
Emulsifier[4] 1 ml. white mineral oil 20 ml., and water to make 100 ml.	1	0.04	—	22.1[2]	—
	0.5	0.17	—	7.2[2]	—
Emulsifier[4] 0.25 ml., kerosene 20 ml., and water to make 100 ml.	6.8	—	—	301	0.4
Emulsifier[5] 0.25 ml., mineral oil 20 ml., and water to make 100 ml.	5.1	—	0.8	249.5	2.1
	2.6	—	0.2	96	0.4
Emulsifier[5] 1 ml., mineral oil 20 ml., and water to make 100 ml.	4.6	1.52	0.78	78.8	0.4
Same, except ears washed with water	7.6	1.16	0.28	62	0
Same, except ears not washed	7.6	.49	0.39	—	—
Emulsifier[5] 5 ml., mineral oil 10 ml., and water to make 100 ml.	7.8	0.83	0.64	217	0
Same, except ears not washed	7.8	0.64	0.80	—	—
Emulsifier[5] 0.25 ml., mineral oil 10 ml., and water to make 100 ml.	6.4	—	0.4	281.5	0.4
DDT, dispersible powder, 1 gm. plus:					
Emulsifier[5] 1 ml., mineral oil 10 ml., and water to make 100 ml.	1	0.15	—	46[2]	—
Emulsifier[6] 0.25 ml., mineral oil 10 ml., and water to make 100 ml.	5	—	—	106.3	0.4
Insecticides Applied by Injection					
DDT, technical:					
2 gm. in 100 ml. of mineral oil	0.5	1.1	—	0.47	—
	0.5	.2	—	29.8[2]	—
1 gm. in 100 ml. of mineral oil	.33	1.31	0.66	4.7	2.7
Gamma benzene hexachloride, 1 gm. in 100 ml. of mineral oil	0.33	0.87[6]	0.17	9.1	0.01
Untreated checks	None	0	—	0	0
		0	—	0	0
		1.01	0.55[7]	—	—
		—	0.25[7]	—	—
		—	0.4[7]	0	0

[1] All determinations made by Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.
[2] Cobs, husks, and silks analyzed together.
[3] An aralkyl polyether alcohol (*Triton X100*).
[4] A condensation product of ethylene oxide and an alkylated cresol.
[5] *Triton B1956*.
[6] Benzene hexachloride.
[7] Supposedly due to contamination from treated samples.

residues on the husks and silks varied from 47.9 to 301 p.p.m. where the more promising emulsions or oil solutions were applied by atomization. Residues of over 96 p.p.m. of DDT were found on the silks and husks only in cases where five or more milliliters per ear of the insecticide was applied.

EFFECTS ON GERMINATION OF DENT CORN SEED.—The germination of seed from ears of a number of dent corn inbreds was not adversely affected by treatments with formulations containing DDT or dichloroethyl ether. The seeds used in the germination tests were from ears that had been treated with white mineral oil or motor oil containing 2 gm. of DDT or 2 per cent of dichloroethyl ether per 100 ml., injected at the rate of 0.5 and 1 ml. per ear. In one series of germination tests, the seedlings from corn treated with mineral oil containing DDT were more vigorous than those from untreated corn.

TASTE, ODOR, AND EFFECTS OF INSECTICIDES ON THE OPERATOR.—Corn treated with an emulsion containing 2 per cent of DDT and 20 per cent of white mineral oil applied by atomization had no disagreeable taste or odor. Corn treated with only 0.33 ml. per ear of white mineral oil containing 1 per cent of gamma benzene hexachloride had such a disagreeable odor and taste that it was inedible. Benzene hexachloride and styrene dibromide were disagreeable to apply in any form. No ill effects were experienced from working with any of the insecticides, although residues of the oil solutions and emulsions remaining on the operators' hands after working with them for some time were difficult to remove. Dichloroethyl ether left a disagreeable odor on ears in some plots. The husks of samples treated with an emulsion containing 1 per cent of chlordan had a slight pungent odor at harvest time. This odor seemed to be transferred to the kernels in the process of husking. Samples of sweet corn treated with emulsions containing deodorized kerosene retained a slight odor of kerosene until harvested as roasting ears. In two cases where motor oil was substituted for mineral oil in emulsions used on sweet corn, no objectionable odor was detected when the ears were harvested.

DISCUSSION AND SUMMARY.—In the tests of 16 insecticides conducted by the authors, DDT, benzene hexachloride, chlordan, and TDE were superior to pyrethrins, dichloroethyl ether, or styrene dibromide when applied to corn ears in oil solutions or emulsions for control of the corn earworm and the fall armyworm. Benzene hexachloride made the corn inedible, however, and corn treated with emulsions containing chlordan or with formulations containing kerosene also had a noticeable odor when harvested. Mineral oil or kerosene solutions were somewhat more effective than any of the emulsions used in these tests.[2] The fall armyworm appeared to be much more easily controlled than the earworm, possibly because of its more roving habits.

None of the insecticides gave satisfactory control of these insects when applied in dust form, in water suspensions or in emulsions containing very small percentages of oil. Two treatments with dusts containing 5 to 10 per cent of DDT applied 1 day apart to ears with fresh silks did not give good control. At least 20 per cent of oil seemed to be required for consistently good control. It is thought, however, that the oil acted mainly as a penetrant and might possibly be replaced by some other material. A sodium sulfate of a higher secondary alcohol tested in 1947 greatly increased the rate of control obtained with an emulsion containing only 5 per cent of oil, but the penetrant itself caused severe burning at the rate used. Emulsions of DDT containing 20 to 30 per cent of white mineral oil were atomized on unfertilized silks in considerable quantities with little loss of tip kernels.

If all ears were in silk at time of first treatment, another application was unnecessary. The duration of the silking period within a field might determine the number of treatments required, but in these tests good control of the worms was obtained and material injury by them was prevented when the first application was 7 or 8 days after the first silks appeared. In many fields this schedule would allow good control of the earworm and fall armyworm with a single application.

Heavy rainfall soon after application of DDT in oil solutions, emulsions containing oil, or water suspensions increased rather than decreased the amount of control secured. The presence of adequate

[2] Later tests, data from which are not included here, resulted in better control through the use of certain DDT emulsions than from oil solutions containing DDT.

moisture apparently increased penetration of the insecticide into the silk channels.

According to evidence obtained in these experiments, proper application of the treatments shown in table 4 will give excellent protection against earworms and fall armyworms attacking the ears of hybrid seed corn or sweet corn grown for market or canning. When used at the dosages indicated, the treatments will not leave dangerous residues or a disagreeable flavor on the kernels, or injure germination. The same formulations and dosages are recommended for either sweet or field corn. However, with the two formulations recommended when the material is to be applied by atomization, the husks, leaves, and stalks should not be fed to dairy animals or to meat animals that are being finished for slaughter because of the excessive residues of DDT likely to be present on them.

Successful large-scale application of DDT and other insecticides would seem to depend upon development of suitable power-driven spray apparatus. To reduce the residue hazard, increase efficiency, and lower costs, a machine dispersing a fine mist seems necessary. The droplets should be small enough to allow them to float momentarily amongst the corn foliage but not be too greatly influenced by a moderate breeze. These tests indicate, however, that the spray must be directed toward the silks to obtain adequate coverage of them and penetration of the silk channels.

Table 4.—Best and safest formulations with methods of application and amounts necessary for contral of the corn earworm and fall armyworm in sweet or field corn.

FORMULATION	HOW APPLIED	QUANTITY PER EAR (MILLILITERS)
Technical DDT in 1 gal. of mineral oil:[1]		
14 to 19 gms.	Injected into silk mass	0.33
70 gms.	As an atomized spray	0.5 to 1.0
Dispersible 50 per cent DDT power 140 gms.[1]		
Plus 19 mls. of emulsifier[2] plus 1 qt. of white mineral oil with water to make 1 gal.	As an atomized spray	2.0 to 3.0

[1] Mineral oil of 80 to 95 sec. Saybolt viscosity at 100° F. recommended where material is to be sprayed and 120 to 125 sec. viscosity where it is to be injected.
[2] *Triton B1956.*

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FOURTH ANNUAL MEETING NORTH-CENTRAL STATES BRANCH

The 1949 meeting of the North Central States Branch of the Association will be held in Milwaukee, Wisconsin on March 24 and 25. The headquarters of the meetings will be in the Hotel Schroeder. The Chairman of the Local Committee on Arrangements is E. L. Chambers and Dr. T. L. Aamodt is Chairman of the Program Committee.

Field Tests of Uniforms Impregnated with Mite Toxicants: I, Protection Studies

H. F. Cross[1] and F. M. Snyder[2]

Serious scrub typhus infections (tsutsugamushi disease) during World War II centuated the need for effective methods of protecting military personnel from attacks by mites (commonly called chiggers or redbugs). Early tests at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine (Madden *et al.*, 1944) demonstrated that the standard insect repellents, especially dimethyl phthalate, would effectively prevent chigger attachments when applied to clothing. Later Major R. N. McCulloch, of the Australian Army (Bushland 1946*a*), showed that the compounds acted primarily as toxicants rather than as repellents. He reported dibutyl phthalate to be more practical than dimethyl phthalate because it was not so easily removed from the uniforms by water. Just as the war ended, benzyl benzoate was adopted by our Army as the standard material for impregnating uniforms. This material was selected because in 1944 it was found to be effective through at least two soap and water washings (Snyder & Morton 1946*a*, *b*), whereas dimethyl phthalate was rendered ineffective by rinsing in cool water (Bushland 1946*a*, *b;* Snyder & Morton 1946*b*).

In a search for chemicals more resistant to washing than benzyl benzoate, about 6000 materials were subjected to screening tests at the Orlando laboratory. Data obtained during the summer of 1946 on the effectiveness of 18 outstanding materials in comparison with benzyl benzoate are presented in this paper. These materials were evaluated both by the protection given to wearers of impregnated uniforms and by the time required to immobilize, or stop, mites confined on impregnated cloth. Studies of the first type are reported in part I and of the second type in part II. Preliminary results with benzil and phenyl benzoate have previously been reported (Snyder and Morton 1946*a*).

Methods.—Cotton herringbone fatigue uniforms and heavy wool socks were impregnated with the test materials at the rate of about 2 grams per square foot of cloth. The clothing was saturated with 1700 ml. of an acetone solution that contained 75 grams of the test material. The treated clothing was worn by research subjects, who sat and lay on the ground for 1 or 2 hours in an area heavily infested with chiggers. A subject wearing an untreated uniform spent the same time in the same area to serve as a check. Three to 5 hours after exposure the chiggers attached to each subject were counted.

Two series of tests were made. In the first series uniforms were impregnated with all the test materials. Since all the treated uniforms were expected to be effective after at least two washings, they were washed twice before any of the tests were begun. In the second series uniforms were treated with five of the materials that appeared to be the most effective in the first series and that did not stain, cause skin irritation, or have an undesirable odor. These uniforms were washed several times and tested after the second, third, sixth, and subsequent washings until they failed to give good protection. A uniform treated with benzyl benzoate and an untreated uniform that was used as a check were included in each series. One to four tests were made with each uniform after each washing, but ordinarily they were tested only twice. Evaluations were made on the basis of the total chigger attachments on subjects wearing the treated uniforms as compared with the attachments on subjects wearing an untreated uniform.

The uniforms were washed individually in an electric washing machine for 10 minutes with 20 gallons of water containing 0.76 per cent of soap. The temperature of the water was 120° F. They were then rinsed twice for 5 minutes each in 20 gallons of cool tap water.

Uniforms impregnated with six of the better materials were hung out-of-doors, where they were exposed to a total rainfall of 16.7 inches during the first 60 days. The mean temperature was 82° F.

Results.—Tables 1 and 2 show the re-

[1] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, working under a transfer of funds from the Office of the Surgeon General, U. S. Army.
[2] Medical Division, Army Chemical Corps.

Table 1.—Results of first series of field tests of clothing impregnated with some of the better mite-killing materials and then subjected to a number of washings. (Dosage 2 grams per square foot.)

Chemical	Washings	Protection Data		Stopping-Time Data[1]	
		Average attachments	Per cent reduction from check	Mites	Average stopping time minutes
Benzene hexachloride (approximately 12 per cent gamma isomer)[2]	4	5	92.2	20	26
	5	24	39.2	10	53
Benzil	4	0	100	20	6
	5	2	96.6	22	10
	6	0	100	30	8
	7	0	100	60	13
	8	0	100	60	14
	9	1	99.1	16	33
	10	2.5	97.3	60	25
	11	30.5	87.5	60	37
Benzoic acid, benzyl ester (benzyl benzoate)	2	0	100	10	2
	3	0	100	35	8
	4	104	0	5	240+
Benzoic acid, *p*-cresyl ester (*p*-cresyl benzoate)	4	0	100	60	5
	5	1.5	97.8	60	11
	6	0	100	60	8
	7	0	100	45	8
	8	2	97.8	60	18
	9	0.5	99.8	60	10
	10	4	94.7	60	11
	11	33	86.6	30	45
Benzoic acid, phenyl ester (phenyl benzoate)	4	0	100	20	4
	5	0	100	15	10
	6	4.5	92.2	60	11
	7	31.5	54.3	60	16
Benzoic acid, 2-thenyl ester (2-thenyl benzoate)	4	1	99.5	35	3
	5	0	100	60	4
	6	1	98.5	60	7
	7	0	100	60	13
	8	5	91.6	45	12
	9	588	0	20	230
Carbonic acid, diphenyl ester (diphenyl carbonate)	4	0	100	40	4
	5	0	100	60	21
	6	0	100	60	17
	7	0	100	30	19
	8	0	100	36	88
	9	6.5	92.9	60	54
	10	57	76.6	60	30
2-Chloroethyl-2-cyclohexylphenyl ether	4	0	100	90	11
	5	14.5	42.0	60	29
Desoxybenzoin[3]	4	3	96.4	60	57
	5	0	100	95	255
	6	46	61.3	60	350+
x-Dichlorodiphenyl ether[3,4]	4	0	100	10	5
	5	0	100	60	22
	6	0	100	83	59
	7	0	100	48	24
	8	0	100	60	62
	9	7	97.1	60	30
	10	615	0	30	39

[1] Detailed data for stopping-time tests are given in the paper following this.
[2] Has a disagreeable odor.
[3] Causes skin irritation.
[4] *x* signifies that the position of the chlorine atom is unknown.

Table 1—(continued)

Chemical	Washings	Protection Data: Average attachments	Protection Data: Reduction per cent from check	Stopping-Tiem Data[1]: Mites	Stopping-Tiem Data[1]: Average stopping time minutes
Octylphenol	4	10.5	91.8	5	165
	5	34	0	10	439
Diphenylnitrosoamine[5]	6	1	99.0	30	8
	7	7	94.8	60	8
	8	8	98.2	60	54
	9	78	2.75	30	300+
Hexachloro-2,5-cyclohexadien-1-one[3]	4	2	97.9	—	—
	5	32.5	79.8	—	—
1-Nitronaphthalene[3]	5	1	99.0	—	—
	6	13	93.5	—	—
	7	54	0	—	—
Phenoxathiin	4	1	98.4	20	5
	5	11	85.2	28	12
	6	78	0	30	247
Salicyclic acid, 2-thenyl ester (2-thenyl salicylate)	4	0	100	30	8
	5	0	100	60	18
	6	0	100	60	27
	7	0	100	30	22
	8	0.5	99.6	46	216
	9	10	90.8	60	116
	10	225	48.9	30	52
Thiocyanic acid, lauryl ester (lauryl thiocyanate) 2	4	0	100	—	—
	5	0	100	—	—
	6	2	88.3	—	—
	7	13	95.2	—	—
	8	185	0	—	—
x-Trichlorodiphenyl ether[3,4]	4	0	100	10	5
	5	2.8	99.4	40	59
	6	43	12.2	30	300+
alpha-Thiocyanopropionic acid, dipentene monocarbinol ester (hydrogenated)[2]	4	6	95.6	—	—
	5	0	100	—	—
	6	46	2.1	—	—

[1] Stains.

sults of the first and second series of tests, respectively. The 5 materials that appeared to be especially promising in the first series of tests were diphenyl carbonate, 2-thenyl salicylate, benzil, *p*-cresyl benzoate, and 2-thenyl benzoate. Diphenyl carbonate gave complete protection through 8 washings and 2-thenyl salicylate through 7 washings. Benzil and *p*-cresyl benzoate gave complete protection through only 4 washings, but 95 per cent protection through 10 washings. 2-Thenyl benzoate gave 98 to 100 per cent protection through 7 washings. Two other compounds, *x*-dichloro-diphenyl ether and diphenylnitrosoamine, gave a high degree of protection through 8 washings, but were eliminated from further consideration because of undesirable properties. For most of the other materials the protection dropped below 95 percent after the third, fourth, or fifth washing. Benzene hexachloride allowed a few attachments after the third washing. Benzyl benzoate gave complete protection through 3 washings, but was ineffective after the fourth. One compound, l-nitronaphthalene, was too irritating to the skin to permit wearing of the uniform until after the fifth washing.

In the second series of tests *p*-cresyl

Table 2.—Results of second series of field tests of clothing impregnated with the most outstanding mite-killing materials and then subjected to a number of washings. (Dosage 2 grams per square foot.)

CHEMICAL	WASHINGS	PROTECTION DATA		STOPPING-TIME DATA[1]	
		Average attachments	Per cent reduction from check	Mites	Average stopping time minutes
Benzil	6	5	95.6	30	16
	7	3	95.9	110	8
	8	1	98.7	60	14
	9	1	99.8	60	13
	10	5	96.5	90	15
	11	6	96.8	90	18
	12	4.6	83.1	60	69
Benzoic acid, benzyl ester (benzyl benzoate)	2	0	100	30	2
	3	1	98.9	110	41
	4	116	0	30	157
Benzoic acid, phenyl ester (phenyl benzoate)	6	0	100	30	10
	7	0	100	60	6
	8	8	97.9	90	20
	9	153	0	30	220+
Benzoic acid, 2-thenyl ester (2-thenyl benzoate)	6	0	100	30	7
	7	30	77.2	170	13
Carbonic acid, diphenyl ester (diphenyl carbonate)	6	0	100	30	3
	7	0	100	90	6
	8	1	99.0	60	9
	9	52	78.9	30	10
Salicyclic acid, 2-thenyl ester (2-thenyl salicylate)	6	0	100	30	13
	7	0	100	90	14
	8	19	74.8	60	20
	9	33	86.6	30	44

[1] Additional data for stopping-time tests are given in part II.

benzoate was inadvertently omitted. Phenyl benzoate was included because of its possible interest to persons working with repellents. Phenyl benzoate, diphenyl carbonate, and 2-thenyl salicylate gave complete protection through 7 washings and 2-thenyl benzoate through 6 washings. Benzil gave better than 95 per cent protection through 11 washings. Benzyl benzoate gave 99 per cent protection after the third washing, and no protection after the fourth.

Diphenyl carbonate and 2-thenyl salicylate gave complete protection and benzil and *p*-cresyl benzoate gave a high degree of partial protection through more washings than any of the other materials tested. 2-Thenyl benzoate afforded less protection after the seventh washing than any of the above-mentioned materials.

Of the better materials aged out-of-doors, diphenyl carbonate gave complete protection through 54 days, but was noneffective after 66 days; 2-thenyl salicylate gave complete protection for 39 days, and 95 per cent protection after 90 days and one washing; 2-thenyl benzoate gave complete protection for 39 days, allowed a few attachments after 47 days, then gave complete protection through the 77 days, but afforded no protection after 90 days and one washing; *p*-cresyl benzoate gave complete protection for 39 days and no protection after 60 days; benzil gave complete protection for 33 days and 94 per cent protection after 90 days and one washing; phenyl benzoate afforded complete protection through only 24 days and no protection after 47 days; the standard material, benzyl benzoate, was ineffective after 21 days.

SUMMARY.—In a search for chemicals more resistant to washing than benzyl benzoate, the material adopted as a stand-

ard by the Army for impregnating uniforms to prevent attachment by mites, the following materials were found to be especially promising: Benzil, 2-thenyl benzoate, *p*-cresyl benzoate, diphenyl carbonate, and 2-thenyl salicylate. Diphenyl carbonate and 2-thenyl salicylate gave complete protection and benzil and *p*-cresyl benzoate gave a high degree of partial protection through more washings than the other materials. Diphenyl carbonate gave complete protection and benzil and 2-thenyl salicylate gave a high degree of protection through more days of aging than the other materials. 2-thenyl benzoate was less effective in washing tests, but in aging tests afforded a high degree of protection over a longer period of time than diphenyl carbonate or *p*-cresyl benzoate.

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Field Tests of Uniforms Impregnated with Mite Toxicants: Part II, Stopping-Time Studies

F. M. SNYDER[1] AND H. F. CROSS[2]

The evaluation of compounds as mite toxicants at the Orlando laboratory has been based primarily on the time required to immobilize or stop mites (chiggers) confined on impregnated cloth (U. S. Bur. Ent. and Plant Quar. 1947). A limit of 15 minutes was arbitrarily selected as the basis for rapid elimination of non-effective materials, since it was observed that chiggers may attach to certain individuals in about that time. Garments impregnated with 2 grams of benzyl benzoate per square foot were found to be effective after two, but not three, launderings (Snyder and Morton 1946*a*, *b*). Swatches of cloth impregnated at the same rate and washed in the same manner as the garments had stopping times of less than 15 minutes after two washings but usually more than 15 minutes after a third washing.

A few stopping-time tests in 1944 on uniforms treated with benzyl benzoate dibutyl phthalate and 2-phenylcyclohexanol seemed to confirm the selection of the 15-minute stopping-time limit. Bushland (1946*a*) working in New Guinea, also used the 15-minute limit. Tests made in 1945 by the Army Chemical Corps and the United States Department of Agriculture (unpublished data), however, seemed to indicate that this stopping time was not completely correlated with the degree of protection. Stopping-time data on uniforms used in tests at the Orlando laboratory are presented in tables 1 and 2 (part I of this paper). These data show the correlation between stopping time and protection of washed, impregnated uniforms.

METHODS.—For each test a swatch about 4 by 4 inches was cut from certain parts of the impregnated uniforms, such as the pockets, one of the double layers of cloth in the fly of the jacket, or from the trouser fly, so that the uniforms could still be used for the protection studies (see

[1] Medical Division, Army Chemical Corps.
[2] U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine, working under a transfer of funds from the Office of the Surgeon General, U. S. Army.

part I). Several samples were used to obtain an accurate evaluation of the stopping time.

From 5 to 15, usually 10, chiggers were confined on each swatch. As far as was practicable, the stopping-time tests were made at the same time and in the same locality as the protection studies. The swatches were pinned to the uniforms when the latter were laundered to insure comparable washing.

RESULTS.—The stopping times were less than 10 minutes after the second and third washings for all chemicals except benzene hexachloride and octylphenol. For these materials they were 21 and 26 minutes and 37 and 42 minutes, respectively. The chiggers were greatly affected within 5 to 10 minutes by these two materials. For all the materials the intervals from the time the chiggers first became affected until they were stopped increased with the number of washings; the rate of increase, however, varied with different chemicals.

The records from all the tests are summarized in table 1. This compilation includes those tests made after the second and third washings. These uniforms were not tested for protection or stopping times when freshly impregnated, after the first washing in either series (see part I), after the second, fourth, or fifth washings in the second series, or after a significant number of attachments had once been received. It is probable that the numbers would have been greater in the 99.5–100 per cent and 0–15 minute group, and in the 0–50 per cent and 31-minute group, had tests been made after impregnation and after each washing.

Table 1.—Correlation between chigger stopping times and per cent protection of clothes impregnated with various insecticides.

PER CENT PROTECTION	NUMBER OF TESTS SHOWING INDICATED STOPPING TIME IN MINUTES						
	0–10 Minutes	11–15 Minutes	16–20 Minutes	21–25 Minutes	26–30 Minutes	31+ Minutes	Total
100–99.5	32	7	4	5	2	7	57
99.4–95.0	5	3	3	1	0	5	17
94.9–90.0	1	3	0	0	2	3	9
89.9–80.0	0	1	0	0	0	4	5
79.9–50.0	0	2	2	0	1	1	6
49.9–0	0	0	0	0	1	11	12
Total	38	16	9	6	6	31	106

In the 74 tests in which protection was 95 to 100 per cent, 63.5 per cent had stopping times below 15 minutes, 20.3 per cent between 16–30 minutes, and 16.2 per cent for 31 minutes or more. In the 18 tests in which protection was less than 80 per cent only 11.1 per cent had stopping times of less than 15 minutes, 22.2 per cent of 16–30 minutes, and 66.6 per cent of 31 minutes or more.

The data in tables 1 and 2 show that in 12 of 16 tests the last washing giving 100 per cent protection had stopping times of 15 minutes or less, but after the next washing only 4 of 16 materials had stopping times below 15 minutes. By including the data after the third washing for the less effective materials, 7 of 21 materials had stopping times below 15 minutes on the last washing giving 100 per cent protection, and over 15 minutes after the next washing.

When there was a large decrease in the percentage of protection after a washing, there was generally a corresponding increase in stopping times.

CONCLUSIONS.—It is concluded from these data that some correlation exists between stopping times and protection, but that no definite limit of time can be set for all materials on the basis of these tests. If stopping times are 15 minutes or less, protection of 90 per cent or more may be expected, but when stopping times are greater than 15 minutes, protection ranging from 0 to 100 per cent may be expected.

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The Use of Guppies in the Toxicological Assay of *Derris* and *Lonchocarpus* Roots

CALEB PAGÁN

Considerable toxicological work has been done in which fish were used as test animals. Gersdorff (1930, 1931) reported results obtained with goldfish in which different compounds extracted from derris roots were tested. Other workers (Carpenter 1927; Dansel 1933) have used minnows and stickle backs in toxicity tests.

As far as is known, there is no report in the literature in which guppies were used as a test animal in assaying the toxicity of insecticidal plants. Likewise, there is no information comparing the toxicological value of such materials with fish and insects.

The object of the present investigation was to develop a simple laboratory method for assaying the toxicity of derris and lonchocarpus roots using guppies, *Lebistes reticulatus*, as test animals. In the course of this work several samples of *Derris elliptica* (Wall) Benth. and *Lonchocarpus nicou* A. C. Smith, previously assayed on houseflies (Jones *et al.* 1948), were tested on guppies in order to establish a comparison.

MATERIALS AND METHODS.—The guppies were chosen as test animals because (1) they were available in large numbers at no cost, (2) they could be obtained at uniform stages of development, and (3) they were easy to handle in the laboratory and required no special food or attention. The fish used in the tests were obtained from the ponds and ditches on the station grounds. The mean length of 150 adult male guppies was found to be 20.2 mm. with a standard deviation of 2.2 mm. and the mean weight 121.2 mg. with a standard deviation of 13.0 mg. Only adult male guppies were selected for the test in order to reduce variation in susceptibility due to sex and age. The selection of adult males was easily made because of their distinct coloring in contrast to the females and young males (Mellen, I.M. 1921).

Two different methods of estimating toxicity were tried. The first method used was essentially the same as the one described by Gersdorff (Gersdorff 1935) in which the speed of toxic action was used as a measure of toxicity. The main objection to this procedure was the fact that close and constant observation was necessary to determine the death point. This was particularly inconvenient at the lower concentrations in which several hours were required for the death point to be reached. Furthermore, as the guppies were caught in their natural habitat, an excessive number of fish were necessary to get reliable data.

In the second method the dosage mortality principle was used and found to be more convenient. The procedure followed in this method was to allow the fish to remain in contact with the toxic solutions for a definite length of time (6 hours was found to give the best results) after which the numbers of dead were counted. In preliminary experiments it was found that mortality of the guppies was proportional to the concentration of rotenone when 1 ml. of acetone solutions ranging from 0.025 to 0.1 mg. per ml. was added to 1 liter of water in which 10 fish were swimming. The log of rotenone concentration plotted against mortality probits resulted in a straight line curve as shown in figure 1(a) (Bliss 1935).

One of the possible limitations of using fish obtained from their natural habitat for toxicity assays is differences in susceptibility due to environmental conditions. Seasonal variation may also affect susceptibility although in the Tropics, where there is no marked change in seasons, this factor may not be too important.

Additional experiments were made in order to study the effect of environmental conditions on the susceptibility of the fish to rotenone. The guppies for these tests were caught at two different locations: on the station grounds, and in a drainage ditch near the city limits almost 2 miles from the station. As these experiments extended over a period of 6 months the date obtained also included some information as to the effect of seasonal variation.

The results from these experiments are presented graphically in figure 1. Lines (*a*) and (*b*) represent the dosage-mortality

relationship with fish caught in the station grounds and (*c*) and (*d*) with fish obtained from the city drainage ditch.

The curves can be compared from two points of view: (1) Median lethal dose, and (2) degree of slope. In our case we are interested mainly in obtaining a dosage mortality curve with rotenone and referring the assayed sample to this line to obtain the rotenone equivalent. It is obvious that the slope is more important in this case than median lethal dose. If we consider the samples from this point of view, two observations can be made: (1) The slope is very steep, and (2) it is the same for the four curves. Statistically, a steep curve indicates that the fish population behaves more uniformly than if the dosage response curve were flat. A consistent degree of slope for log-probability lines indicates that the rate of change in toxicity per unit change in dosage remains constant. It is evident from these lines that the source is a strong factor in the susceptibility of the guppies to rotenone. It is suggested, therefore, that a preliminary run be made to determine a suitable range of concentration of the toxic agent for the fish in hand before proceeding with the unknown samples.

The next step was to apply the test to samples of derris and lonchocarpus roots There were available five samples of *Derris elliptica*, two of *Lonchocarpus nicou*, and one sample of *L. chrysophyllus* Kleinh. These samples had been previously evaluated for toxicity on house flies, (*Musca domestica* L.).

The test solutions of the root samples were prepared by extraction with acetone and diluting the extract so that 1 ml. of acetone solution of each sample contained 0.025 mg. rotenone. One ml. of this solution was added to 1 liter of water and thoroughly mixed. The test solutions of rotenone standards were similarly prepared with rotenone at the following concentrations: 0.025 0.0375, 0.05, and 0.1 mg. per ml. of acetone. A control solution consisted of 1 liter of water to which 1 ml. of pure acetone was added.

For the tests, 700 male guppies were distributed into 10 lots of 70 fish each. One fish was selected at random from each lot and transferred into a 250 ml. beaker half-full of water. The constant movement of the fish helped in the chance selections. When 10 fish had been caught in this manner the water was drained off and the guppies transferred immediately into the jar containing 1 liter of test solutions. Each test solution was replicated 5 times. Thus with 10 fish in each replication there were a total of 50 fish per treatment. The jars were arranged in a randomized block design.

Approximately 2 hours were required to set up the experiment, including the preparation of test solutions, and the randomization of the fishes.

RESULTS AND DISCUSSION.—Soon after the fish were put in some of the test solutions several of them showed signs of poisoning and a few minutes later were

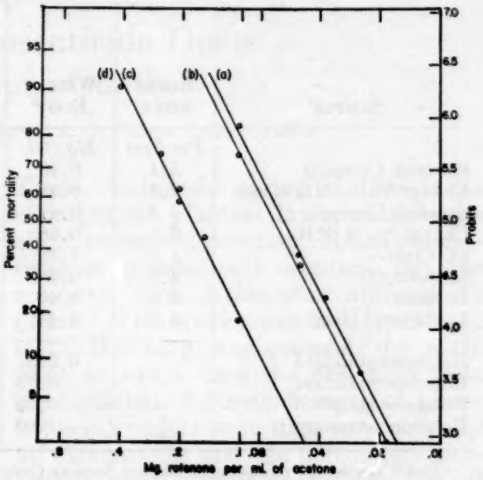

FIG. 1.—Effect of source and season on the dosage mortality curves obtained with guppies. Lines (a) and (b) represent the dosage mortality relationship with fish caught in the station grounds, and lines (c) and (d) with fish obtained from a city drainage ditch.

dead. It was observed during the course of the experiment that fish swimming strong and to all appearances healthy would suddenly appear ill, turn on their sides, and die within a few minutes. This behavior was advantageous because when the final mortality counts were made the calculations were not complicated by moribund or visibly affected animals as is the case when insects are used as the test animal.

The mortality was computed at the end of 6, 24, and 48 hours. Of the total dead, 90 per cent were killed in the first 6 hours. None of the fish in control solutions were dead at the end of this period.

Since there was no improvement in the results when the exposure time was extended to 24 and 48 hours, the mortality at 6 hours was taken as a basis for calculations.

The mortalities obtained with the standard test solutions were plotted on a log probability paper against the dosage, the resulting line is shown in figure 1 (*1*). The per cent mortality of each of the samples was referred to this line to obtain the rotenone equivalent. The results are presented in table 1. The rotenone equivalent of the samples as determined on house flies is also included in table 1 for comparison with the rotenone equivalent found with guppies. The toxicity data on house flies was determined on adult insects, reared by standard procedures, by the turntable method, 8 tests being made on each material with approximately 150 flies to each test.

The agreement between both sets of data is very close. The order of toxicity of the samples is the same and the rank based on the mortalities is very similar in both cases. The actual values for rotenone equivalent determined on house flies and guppies are in surprisingly close agreement when we consider the wide difference in technique and test animal. It is evident from these data that for all practical purposes the toxicity to guppies and houseflies of derris and lonchocarpus roots is essentially the same. It has been shown that toxicological data obtained with houseflies is in good agreement with that obtained with Mexican bean beetle. In view of this fact it seems valid to substitute guppies as a test animal in the biological assay of derris and lonchocarpus roots.

The advantages of the guppies as test animals are considerable. These are as follows:

1. In tropical countries guppies can be caught easily in large quantities in ponds and ditches. Rearing of guppies, when required, is relatively easy and does not require special equipment.

2. No special apparatus or technique is required.

3. Results are obtained in a relatively short time, usually 1 day.

SUMMARY.—1. A quick, simple method for biologically assaying derris and lonchocarpus roots using guppies as a test animal is described.

2. The toxicity data (rotenone equivalent) obtained with guppies was in close

Table 1.—The toxicity to guppies and house flies of some derris and lonchocarpus roots.

Sample[1]	Rotenone	Weight Root[2]	Mortality 6 Hours[3]	S.E.	Rotenone Equivalent[4]		
					Guppies		Houseflies[5]
					Test solution	Root[6]	Root
	Per Cent	*Mg./ml.*	*Per Cent*	*Per Cent*	*Mg./ml.*	*Per Cent*	*Per Cent*
Sarawak Creeping	5.4	0.46	44	7.5	0.0530	11.45	12.00
Changi No. 3, MG clones	7.3	0.34	24	2.0	.0375	10.95	11.17
Sarawak Creeping (1)	5.3	0.47	20	5.5	.0345	7.30	7.72
Changi No. 3, P.R.	3.7	0.68	22	6.7	.0355	5.26	5.67
St. Croix	1.8	1.39	46	6.8	.0550	3.95	4.24
L. nicou (1)	4.7	0.53	32	5.8	.0430	8.05	8.03
L. nicou	5.5	0.46	16	4.0	.0315	6.92	7.69
L. chrysophyllus	5.7	0.44	12	3.8	.0280	6.40	6.06
Rotenone standard		0.025	8	3.8			
Rotenone standard		.0375	24	11.3			
Rotenone standard		.0500	38	7.4			
Rotenone standard		.1000	82	5.8			

[1] First 5 samples are varieties of *D. elliptica*. Sarawak Creeping (1) grown in Guatemala and *L. nicou* (1) in South America; th rest grown in Puerto Rico.
[2] Weight of root powder times per cent rotenone gave desired concentration of rotenone in test solution, i.e., 0.025 mg./ml.
[3] Differences among mortalities greater than 17 per cent are significant at odds of 19:1.
[4] Rotenone equivalent is the amount of rotenone the sample would need to contain in order to give the kill actually found.
[5] As determined in house flies by Jones *et al.* of the Bureau of Entomology and Plant Quarantine. Differences among the mean mortalities greater than 6 per cent are significant at odds of 19:1.
[6] Rotenone equivalent in test solution divided by weight of root gives rotenone equivalent in root.

agreement with that obtained with houseflies.

3. The advantages of using guppies as test animals for the toxicological assay of derris and cube roots are considerable, particularly in the simplicity and rapidity of the method.

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Comparison of Insecticide Dusts for Grasshopper Control[1]

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Results of tests conducted at this Station during 1947 indicate that chlorinated camphene, benzene hexachloride and chlordan dusts are more effective against grasshoppers than poison baits. Some planters were forced to use these dusts on cultivated crops as a protection against invasions of grasshoppers coming from weed fields and pastures which had been persistently baited. Satisfactory control was obtained even against large nymphs and adults, however, high dosages of the dusts were required. Large populations of grasshoppers survived the baiting operations in 1947, and it was evident this spring that excessive numbers of nymphs would be hatching in practically all weed fields, pastures, etc. Planters in this section of the Brazos river valley organized and dusted all such fields soon after the hatch was completed. It has been estimated that a million or more pounds of dusts were applied to a comparatively small area. Many of these commercially dusted fields were observed and in most instances excellent control was obtained. Thousands of acres of pastures were dusted with chlorinated camphene without removing the livestock. To date, no injury to animals has been reported.

The cage and field tests herein reported were conducted near College Station, Texas, during the spring of 1948 in an effort to aid planters in formulating an effective control program. Mixed populations of grasshoppers occurred, but the majority were *Melanoplus differentialis* (Thos.). This species was used in all cage tests. Hatching was complete by early May at which time the first field tests were started. Untreated cages of grasshoppers or plats were used in practically all experiments and the percentage mortalities were calculated by the use of Abbott's formula. In the two instances in which mortalities are shown following airplane applications, percentages of reduction are given since populations from untreated areas in close proximity to these fields could not be obtained.

CAGE TESTS.—These tests were conducted for the purpose of comparing the toxicity, both as a contact and as a stomach poison to grasshoppers of (1) 3 per cent gamma benzene hexachloride-50 per cent sulphur, (2) 10 per cent chlorinated camphene-75 per cent sulphur, (3) 10 per cent chlordan-80 per cent sulphur and (4) 2 per cent parathion-inert dusts. In tests to determine the relative toxicity of the materials as a contact poison only the nymphs were dusted. Field collected nymphs were placed in coarse wire cages for dusting. The dusts were applied in a dusting chamber containing the caged nymphs and were al-

[1] Technical contribution No. 1163 Texas Agricultural Experiment Station.

lowed to settle 30 seconds before removing the insects. They were immediately transferred to screen cages and thereafter given clean food. Observations for dead individuals were made at 24-hour intervals during a 4-day period. Varying dosages of each material were applied. This entailed the use of approximately 400 individuals in order to determine each toxicity curve.

The toxicity curves shown in figure 1

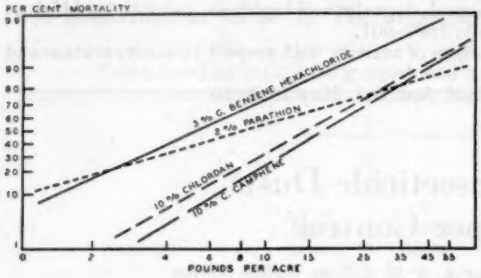

FIG. 1.—Dosage-mortality curves for the toxicity of the insecticides indicated above to grasshopper nymphs.

were calculated by the method described by Bliss (1938). These data show the comparative effect of these materials as a contact poison. Benzene hexachloride and parathion proved more effective as contact poisons than either chlorinated camphene or chlordan. The MLD for each insecticide used is shown in table 1.

Table 1.—The median lethal dose of insecticidal mixtures as indicated below for third instar grasshopper nymphs.

TREATMENT	MLD POUNDS PER ACRE
10% Chlorinated Camphene- Sulphur	17.3
10% Chlordan-Sulphur	14.9
2% Parathion-Inert	8.4
3% Gamma Benzene Hexachloride	5.5

In other cage tests shown in table 2, cotton plants were dusted under a cylinder with a pre-determined dose of each of the above named insecticide dusts. A screen cage was placed over the dusted plants and approximately 35 field collected nymphs were released in each cage. Observations for dead individuals were made at 24-hour intervals during a 5-day period. It was assumed that the results of these tests were principally the action of stomach poisons.

The rapidity of the action of each insecticide principally as a stomach poison is indicated by the percentages of mortality shown in figure 2. Parathion and

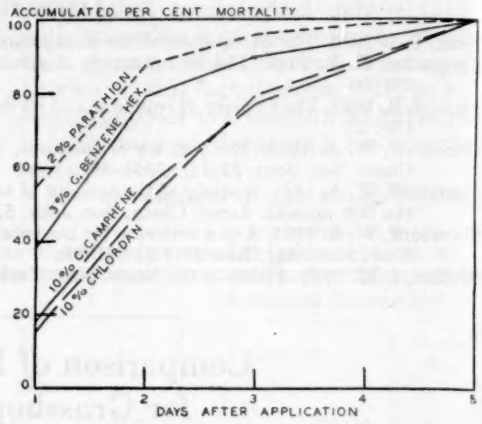

FIG. 2.—The accumulated percentage mortality on successive days as indicated following the application of the materials.

benzene hexachloride were the quickest acting materials, killing nearly 80 per cent of the population within 48 hours. Chlorinated camphene and chlordan were slower acting poisons.

FIELD TESTS.—These tests, table 3, were conducted for the purpose of comparing the same insecticide dusts as used in the cage tests under field conditions. Since the applications were made early in the morning while the air was calm and dew was present, the insecticides acted both as a contact and a stomach poison. The plats were arranged in randomized blocks varying in size from one-seventh to one-quarter acre. The population was estimated by sweeping the plats with a 16-inch insect net. The initial population on the various plats averaged approximately 400 nymphs per 50 sweeps. The number of insects collected in 50 sweeps before and at 24-hour intervals after each application was used to calculate the percentage mortalities. In most cases the young nymphs were not migrating into or out of the plats. The results of these tests indicate that 10 per cent chlorinated camphene-sulphur, 10 per cent chlordan-sulphur, 3 per cent gamma benzene hexachloride-sulphur and 2 per cent parathion dusts were about equally effective against first and second instar nymphs. All dusts should be applied at the rate of at least

Table 2.—Mortality of grasshoppers following dust applications to caged cotton plants. (Three cages in each test.) Rate of application, 16 lbs. per acre.

PER CENT CONCENTRATION	TREATMENTS	NUMBER INSECTS	PER CENT MORTALITY AFTER DAYS INDICATED				
			1	2	3	4	5
			3rd Instar Nymphs				
10	Chlorinated camphene-sulphur	74	24.2	57.3	80.0	83.1	89.2
10	Chlordan-sulphur	98	20.8	45.9	75.6	80.3	88.4
3	Gamma benzene hexachloride-sulphur	114	70.7	82.3	91.0	92.0	93.0
2	Parathion-inert	104	59.6	77.2	84.7	86.9	86.9
			4th Instar Nymphs				
10	Chlorinated camphene-sulphur	116	0.0	20.1	24.8	43.2	91.8
10	Chlordan-sulphur	115	0.0	0.0	2.8	24.1	69.7
3	Gamma benzene hexachloride-sulphur	99	0.0	29.4	23.2	52.9	36.0
2	Parathion-inert	123	48.1	60.5	58.2	58.8	51.1
			5th Instar Nymphs				
10	Chlorinated camphene-sulphur	106	9.6	30.0	38.1	53.9	59.3
10	Chlordan-sulphur	110	11.6	26.9	38.7	43.0	48.9
3	Gamma benzene hexachloride-sulphur	114	15.1	31.2	41.5	46.2	48.2
2	Parathion-inert	108	19.1	29.3	36.3	36.9	36.9
			Adults (Test A)				
10	Chlorinated camphene-sulphur	97	4.1	10.2	25.8	41.3	45.3
10	Chlordan-sulphur	95	0.0	5.4	29.1	46.8	45.9
3	Gamma benzene hexachloride-sulphur	85	28.5	63.2	60.4	59.1	59.4
2	Parathion-inert	92	67.6	83.7	86.7	84.9	86.0
			Adults (Test B)				
10	Chlorinated camphene-sulphur	112	0.0	52.3	76.2	81.5	90.9
10	Chlordan-sulphur	106	0.0	47.5	77.1	85.6	89.0
3	Gamma benzene hexachloride-sulphur	113	0.0	64.5	79.6	82.8	91.0
2	Parathion-inert	103	9.1	89.2	94.1	96.0	100.0

Table 3.—Mortality of first and second instar grasshopper nymphs following dust application in pastures.

TREATMENT	POUNDS PER ACRE	PER CENT MORTALITY AFTER INDICATED NUMBER OF DAYS								
		1	2	3	4	5	6	11	13	14
10% Chlorinated camphene—75% sulphur	9.0	80.2		89.1	84.1	99.6		90.8		
	9.3	82.8	66.3	83.0		81.3	91.1		95.5	
	10.2	32.1	100.0	100.0		98.5	98.6		99.1	
	11.2	99.8	100.0	100.0	100.0		100.0			100.0
	12.0[1]	71.8		92.4	94.2		98.3			
	13.0[1]	77.0	81.2	93.1	90.4		96.7			
	15.4	98.5	99.7	99.2	100.0		100.0			100.0
	16.0	92.5		98.4	97.3	97.7		96.9		
10% Chlordan—80% sulphur	8.5	49.4		46.0	74.9	74.3		82.7		
	9.8	97.2	99.8	99.9	100.0		100.0			98.3
	12.1	63.8	81.8	98.9		84.8	95.6		90.1	
	15.0	96.2		98.6	98.1	92.7		99.1		
	20.3	100.0	100.0	100.0	100.0		100.0			100.0
	27.6	58.0	86.1	92.3		96.7		95.2		90.4
3% Gamma benzene hexachloride—50% sulphur	9.3	41.5	49.5	86.3		94.8	76.1		76.0	
	9.5	98.5		60.4	46.8	75.4		69.9		
	11.1	98.5	99.1	100.0		100.0	98.2		97.8	
	12.0	97.6		90.7	97.4	90.1		86.0		
	14.7	97.8	99.4	98.9	100.0		99.7			99.6
	19.6	97.9	97.2	100.0	99.0		97.2			100.0
2% Parathion-inert	10.0	96.3		83.2	81.3	73.0		77.7		
	10.2	95.1	97.9	100.0		97.9	98.5		97.0	
	12.1	96.2	100.0	97.9		98.4	94.7		86.2	
	12.6	98.9	100.0	100.0	100.0		100.0			100.0
	14.0	100.0		100.0	100.0	93.3		94.4		
	17.5	99.6	100.0	100.0	100.0		100.0			100.0

[1] Airplane applications.

10 pounds per acre. It will be noticed that the mortality was low on those plats receiving lower weights of poison. Later, during June, large nymphs and adults migrated from weed fields and pastures to cultivated crops. These crops were successfully protected, but it was necessary to increase the dosage greatly. From 2 to 3 pounds of technical chlorinated camphene or chlordan per acre was needed adequately to protect such crops as corn and cotton. For a quick kill, high dosages of either benzene hexachloride or parathion should be used.

SUMMARY.—The contact action of benzene hexachloride and parathion was more effective than chlorinated camphene or chlordan. The action of the four materials represents a combination of contact and stomach-poison. Due to the contact action, benzene hexachloride and parathion gave a quicker kill than either chlordan or chlorinated camphene. In order to obtain maximum benefit from the contact action the materials must be applied under good dusting conditions.

The following dusts applied at the rate of 10 pounds per acre gave excellent control of first and second instar grasshopper nymphs: 10 per cent chlorinated camphene-sulphur, 10 per cent chlordan-sulphur, 3 per cent gamma benzene hexachloride-sulphur and 2 per cent parathion-inert. A considerably higher dose was necessary to adequately control fifth instar nymphs and adults especially in cultivated crops. One early application made just after the hatch was completed practically eliminated the pest in weed fields and pastures.

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Cabbage Caterpillar Insecticide Tests[1]

L. E. DILLS and M. L. ODLAND[2]

The most important leaf eating insects on cabbage and related crops in Pennsylvania are the imported cabbageworm, *Pieris rapae* (L.), and the cabbage looper, *Trichoplusia ni* (Hbn.). Usually imported cabbageworms are more abundant during early summer and cabbage loopers become relatively more numerous during late summer and early fall. Experiments designed to test the value of 14 materials for the control of these two insects on cabbage were conducted in 1946 and 1947.

METHODS Since it has been shown (Huckett 1936) that the larvae of the imported cabbageworm and cabbage looper are not equally susceptible to toxic compounds it is necessary when testing insecticides to know the relative abundance of each species. On September 5, 6 and 7, 1946 when the per cent control was determined in the experiments for that year, the infestation consisted of 79.1 per cent imported cabbageworms and 20.9 per cent cabbage loopers. A year later the relative abundance of these two species was reversed. On September 9 and 10 1947, the infestation consisted of 7.6 per cent imported cabbageworms and 92.4 per cent cabbage loopers. Observations indicated that earlier in the season the imported cabbageworm was relatively more abundant.

In both seasons the field plot arrangement was a randomized block with six replications. In 1946 each plot consisted of four rows with twenty plants to a row. Records were taken only from the two center rows while the outer rows served as buffers. The 1947 plots consisted of two rows, each having 19 or 20 plants. An untreated buffer row was left between plots. The variety used was Penn State Ballhead.

The materials were all applied as dusts, pyrophyllite being used as the carrier. A crank-type duster was used in making the

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applications and a special effort was made to apply the same amount of material to each plot. In 1946, six applications were made at intervals of slightly more than a week while in 1947 three applications were made at intervals of 2 to 3 weeks.

Early in September, an average of approximately 28 plants in each plot were selected at random and rated for feeding injury on a scale from 1 to 10. Yield records were taken in the latter part of October. All plants in the two center rows of the plots for 1946 and all the plants in the plots for 1947 were graded as marketable or unmarketable. The marketable heads were cut and further graded as to soft or solid and yield weights were determined.

MATERIALS:—

Benzene hexachloride—1946, 31.6 per cent wettable powder containing 3.8 per cent gamma isomer and 27.8 per cent other isomers; 1947, 25 per cent wettable powder of a technical grade of pure gamma isomer.
Calcium arsenate
Chlordan—50 per cent wettable powder
Chlorinated camphene—37.3 per cent dust concentrate
Cube root containing 5 per cent rotenone
1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane—50 per cent wettable powder
DDT—50 per cent dust concentrate
Lead arsenate
2-Mercapto-6-nitrobenzothiazole
Methoxychlor—50 per cent composition
Activated pyrenone dust base containing 2.5 per cent piperonyl cyclohexenone and 0.2 per cent pyrethrins
Pyrophyllite
Ryania—finely ground stems
Sabadilla—50 per cent sabadilla seed concentrate
Zinc fluoarsenate containing 32.5 per cent arsenic expressed as As_2O_5

RESULTS.—The feeding rating for the plants in each plot was averaged and the data were treated statistically. In order to facilitate interpretation of the results, the ratings have been changed into percentages of control and are given in table 1. No injury from feeding has been given the rating of 100 per cent control while the untreated plots have been given a rating of 0 per cent. Some feeding occurred before any of the applications were made and this lowered the percent of control.

Table 1 shows that all concentrations of DDT tested gave excellent results both years in preventing damage from the imported cabbageworm and the cabbage looper. Huckett (1946) reported that

Table 1.—Dusting experiments with cabbage caterpillars.

INSECTICIDE	PER CENT CONC. DUST	1946 PER CENT CONTROL	1947 PER CENT CONTROL
DDT	1	—	81.9
DDT	2	87.5	87.5
DDT	3	88.9	87.6
Dichlorodiphenyl dichloroethane	3	—	87.0
Methoxychlor	3	—	60.9
Chlordan	3	—	72.6
Chlorinated camphene	3	—	80.8
γ Benzene hexachloride	0.38	84.2	—
γ Benzene hexachloride	1	—	92.7
Rotenone	0.75	85.8	35.5
Ryania	30	83.1	—
Ryania	40	—	46.0
Sabadilla (seed)	10	84.5	—
Pyrethrum dust base[1]	20	78.6	—
Lead arsenate	20	77.6	—
Calcium arsenate	20	—	0
Zinc fluoarsenate	20	26.0	—
2-Mercapto-6-nitrobenzothiazole	10	3.8	—
Untreated	—	0	0
Difference required for significance at 5% level		11.4	14.0
Difference required for significance at 1% level		16.4	18.6

[1] *Pyrenone No. 100.*

when the cabbage looper was the most abundant species, a 2-per cent dichlorodiphenyl dichloroethane dust was slightly less effective than DDT in preventing damage from caterpillars attacking cauliflower. In 1947 when the cabbage looper predominated a 3-per cent dichlorodiphenyl dichloroethane dust was used. At this concentration the control obtained was almost identical with that obtained from either 2 or 3 per cent DDT. In the same experiment methoxychlor and chlordan were found to be inferior to DDT and dichlorodiphenyldichloroethane. More feeding occurred in the plots treated with a chlorinated camphene than in those treated with DDT but the difference was not significant.

For the year 1946, when the imported cabbageworm predominated and applications were made at more frequent intervals, benzene hexachloride dust containing 0.38 per cent gamma isomer gave quite satisfactory results. In 1947, with the gamma isomer increased to 1 per cent and the dust used at less frequent intervals on an infestation where cabbage loopers predominated, only partial control was obtained.

It has been shown (Huckett 1940) that rotenone is effective when used for imported cabbageworms but less satisfactory against loopers. Likewise in this test the rotenone proved to be most effective when the imported cabbageworm was most prevalent. It should be noted

that a larger number of applications were made in 1946 and this no doubt influenced the results. *Ryania* at 30 per cent showed considerable toxicity in 1946 to the imported cabbageworm, but when used in a smaller number of applications in an infestation with a much higher relative per cent of loopers the following year, it gave less satisfactory results. The data in table 1 suggest that further trials with *Ryania* 40 per cent would show it to be superior to 0.75 per cent rotenone dust for the cabbage looper, although it was not found to be equal to any of the concentrations of DDT tested.

In 1946, six applications of a dust composed of 10 per cent sabadilla seed gave quite satisfactory results in preventing damage from the imported cabbageworm. In the same year it was found that there was more feeding on the pyrethrum dust base and lead arsenate plots than on the DDT plots but the difference was not significant. Calcium arsenate has been found to be an ineffective control for cabbage caterpillars (Hervey & Palm 1934). Three applications of a 20 per cent calcium arsenate dust gave a control rating of 0 in 1947, however the yield from the treatment was statistically higher than from the untreated plots. One year's work using zinc fluoarsenate at 20 per cent and 2-mercapto-6-nitrobenzothiazole at 10 per cent showed them to have little merit in preventing feeding from cabbage caterpillars, therefore no further work was done with these materials.

Yield records were taken both years but they are not considered as reliable as the feeding data given in table 1. Disease conditions appeared to be at least partly responsible for considerable variation in yields. In 1946, a very favorable fall for growth gave the plants a chance to outgrow much of the earlier insect damage. In spite of these hinderances to obtaining reliable information on the effect of insect feeding on yield, the harvest weights tended to corroborate the feeding records. In 1946, the highest yields were in the plots treated with DDT, 3 per cent. They were significantly higher than the check but not significantly higher than a number of the other treatments. For 1947, yields from all treatments were significantly higher than the untreated plots. No significant differences in yields were found in the plots treated with benzene hexachloride, chlordan, chlorinated camphene, dichlorodiphenyldichloroethane, DDT 3 per cent, and DDT 1 per cent.

SUMMARY.—The results of 2 years of insecticide treatments on cabbage infested with the imported cabbageworm and the cabbage looper are reported. Fourteen different materials used as dusts were tested and their toxicity to these two species of caterpillars is discussed. Some of the compounds were tested both years and several of them at more than one concentration.

DDT used as a dust was found to be an excellent material for preventing damage from the imported cabbageworm and the cabbage looper.

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The Biology of *Aëdes trivittatus*[1]

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Aedes trivittatus (Coq.) is a rural mosquito and one of the extremely annoying species that breeds in temporary pool sites. Field observations were made on the habits of the immature and adult stages. The life history was studied both in the field and in the laboratory. The field observations for this study were made during the last spring and summer of 1946 and of 1947, in an open wild area along the east bank of the Olentangy river about one mile north of The Ohio State University campus.

BIOLOGY OF *Aëdes Trivittatus*—

Geographical Distribution.—According to Carpenter et al. (1946) *Aëdes trivittatus* is widely distributed in Southern Canada and in the United States, south to South Carolina and Louisiana, and west to Colorado and Montana. Howard, et al. (1917) recorded the species from Mexico and Central America.

Adults of this species have been collected in the following Ohio counties: Champaign, Delaware, Fairfield, Franklin, Guernsey, Licking, Lucas, Morrow, Portage and Wyandot.

Adult and Larval Habitats.—This is a mosquito of open areas and is seldom found in large numbers in the shelter of dense trees. Its typical habitat is a swamp forest. It does not appear to have very strong migratory instincts, as it was seldom caught in the residential area just outside its breeding place.

The larvae were taken during the second half of July 1947 from temporary rain pools of moderate depths, following heavy rains which transformed a number of shallow ditches in the breeding area into these temporary pools. These pools were characterized by the presence of considerable vegetation which covered the ground. This species overwinters in the egg stage and the adults first make their appearance in the field during the first week of June. Collecting records show that adults of this species are available in the field from the first week of June until the first week of September. Only in one case has this species been found at a later date. This was on September 19, 1947 when a few larvae were taken from a flood water pool in Franklin County.

It was noticed from observations that dusk was the best time for collecting females of this species, as at that time they leave their hiding places amidst the grasses and thick vegetation and fly around. During the daytime, and even in bright sunlight, they will bite if the vegetation in which they hide is disturbed. On windy days they remain in the vegetation and are hard to collect.

FIG. 1.—Pupae of *Aëdes trivittatus* (Coq.) hanging to the surface film of the water before adult emergence.

Duration of Adult, Larval and Pupal Periods.—Under natural conditions, collection records indicated that females might live five to six weeks. Males had by comparison a very short life span; none were collected from the field five days after emergence.

The duration of the larval instars and the pupal period vary considerably in nature, since temperature is one of the main factors affecting development, and vagaries of the weather largely determine the length of time passed in any stage. The following data were taken from the

[1] Contribution from the Department of Zoology and Entomology.

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field after a heavy rain which fell on July 13, 14 and 15, 1947 and transformed large areas into temporary pools. When first examined on July 16, the pools contained very large numbers of first instar larvae. They changed to the second instar on July 17. On July 18 the third and fourth larval instars were collected, and on July 19 the fourth larval instar was dominating the pool. The fourth larval instar remained till July 22, when the

FIG. 2.—Newly emerged adult *Aëdes trivittatus* (Coq.) resting for a brief period along the edge of the temporary rain pool before their flight to the near-by wild vegetation where they matured.

change to pupae took place. The pupal period was very brief as adults began to emerge on July 23. The pH value of the water of the pools was taken daily by means of a portable pH comparative meter and was found to be 7.5 ± 0.1.

The temperature of the water varied between 65° and 70° F. during the period of observation. In brief, it took about 1 day for each of the first, second and third larval instars to change from one stage to the next. It took about 3 to 4 days for the fourth larval instar to change to the pupal stage. So in the field, the minimum period from hatching of the eggs to the first emergence of the adult, was about 8 days.

Under laboratory conditions at a temperature of about 80° F., the minimum period from hatching of the egg to the emergence of the adult was 6 days. The maximum period was 10 days.

Larval Associations.—In these temporary rain pools the immature stages of two species of mosquitoes, namely, *Aëdes vexans* and *Psorophora ferox*, were always associated with those of *A. trivittatus* whenever collections were taken for examination.

Habits of the Larvae.—The smaller larvae were observed to remain at the surface of the water in the pool feeding on the micro-organisms. As they developed, they spent more and more time in the lower strata of the water. The large fourth instar larvae were rarely seen at the surface and spent most of the time concealed in the vegetation at the bottom of the pool. This behavior plus the short life span of the larval period are perhaps the chief reason why so many authors report failure to obtain larvae although they find adults very numerous and annoying.

Habits of the Pupa and Emergence of Adult.—Once the change to pupal stage took place, the pupae were observed congregated in large clusters along the margin of the pool and were hanging to the surface film of water by their respiratory trumpets (Fig. 1). This habit of congregating near the edge of the pool may be considered a provision for the emergence of the adult mosquito. The pupal case splits along the median keel present on the dorsomeson of the cephalothorax and the young adult emerges and stands for a while on the pupal skin and then crawls over the edge of the pool where newly emerged adults were observed to remain for from 1 to 2 hours (Fig. 2) before they flew to near-by vegetation, the most common of which were the wild Virginia rye, festuca grass and blue grass, where they spent their maturation period.

It was noticed that most of the early emerged adults were males whose antennal hairs were still folded. The number of females emerged on July 23 was very small. On July 24 the number of emerged females increased. Various attempts made to get these newly emerged females to halt on the author's arms for a blood meal were unsuccessful. On July 25, the males caught from the field were observed to have the hairs on their antennae fully extended. Beginning July 27 the number of males in the field began to diminish and on July 29, the males were very difficult to find in the field, in fact they seemed to have disappeared completely,

and probably they had died. Beginning July 27 the females readily took blood meals and this behavior reached its maximum by July 28 and thereafter up until the end of the active season which is the first week of September.

It seems very possible that by the time the males are able to copulate, mating takes place with the newly emerged females which immediately start search for a blood meal. As was observed from the behavior of these newly emerged females, it seemed very likely that mating is an impulse to their biting habit.

Relation of Blood Meal to Ovarian Development.—In an experiment to ascertain the effect of a blood meal on the development of the ovaries, two series of females totalling 68 individuals were caged individually in a separate oviposition vial as is described in the section on oviposition and left under identical conditions which were those of the laboratory. These fefemales were caught on August 4 from the field as they came to bite. Series A consisted of 27 individuals which were not allowed to have a blood meal, but were caught immediately as they halted on my arms to get a blood meal. The abdomen in all, save two, remained compressed, and dissection of five of them indicated no appreciable ovary development. Most of the specimens remained alive in the tubes for 6 to 7 days. Of the two individuals, one died at the end of the fourth day, after laying two eggs, and the other at the end of 3 days after laying five eggs. When these were dissected they were found to contain well developed eggs. It may have been that these two females had obtained a blood meal before they were collected.

In series B, which consisted of 41 individuals, all were caged after being engorged with blood. About 65 per cent laid eggs after 3 or 4 days. Dissections of all specimens following death, showed the ovaries to contain well developed eggs.

The minimum period between obtaining a blood meal and oviposition was 3 days, but in many individuals 4 to 5 days elapsed before egg laying. It was noted that the blood meals were invariably digested by the time oviposition occurred.

Oviposition.—In the laboratory, the bood engorged adult mosquitoes were isolated, each in a glass shell vial 65 by 22 mm having a damp cotton layer in its bottom. The mouth of the vial was closed by means of a piece of muslin held in place by a small rubber band. Under laboratory conditions with temperature fluctuating between 80° and 85° F. it took a nimimum of 3 days for the blood-fed females to deposit their quota of eggs.

Egg-laying took place during the night on damp cotton in shell vials. The eggs may be unevenly scattered, but were usually laid in small batches. The eggs were usually all laid at about the same time, although in two instances egg-laying occupied a period from 24 to 48 hours in which cases additional eggs were laid after the initial oviposition.

An examination of the ovaries after the matured eggs had been laid showed further minute ova in much the same condition as in freshly emerged specimens. It is possible that in nature, a second batch of eggs might be developed under some circumstances, but under laboratory conditions the females almost invariably died within a few hours of oviposition and in many instances did not move from the last batch of eggs laid. The maximum was 100 eggs oviposited by one female and the minimum of one egg was laid by another, with an average of 55 eggs.

Sites of Human Body Used by the Adult Females to Bite.—A study was made as to the different sites of the observer's body the adult female perferred for a blood meal. It was found that most of the uncovered parts of the body are frequented but with markedly different frequencies as can be seen in table 1.

From table 1, it is apparent that the fore limb is the most desirable site in the human body which attracts this species. It is interesting to note that the females prefer the places on the head which are not thickly covered with hair as for instance, behind the ears or between or just above the eyebrows.

More than once, attempts to bite through a white thin-woven T-shirt were unsuccessful.

Biting Habit of the Female Aëdes trivittatus.—The following description is made from observation of a number of females of this species during the act of biting.

Once a female comes to rest over a biting site, for example, an arm, it starts to walk around the area where it alighted. With the labellae of the proboscis touching the skin surface, it continues to do that for 1 to 3 minutes. All of a sudden the

stylets are inserted inside the skin; simultaneously a very painful irritation of this spot of the skin is felt which lasts for about 30 seconds. By this time nearly half of the length of the stylets is inserted into the skin, then the mosquito withdraws its stylets and waves the proboscis around the puncture and after about 30 seconds the stylets are inserted again and another very painful irritation is felt. This time the stylets are pushed inside the skin about two-thirds of their length and the mosquito has its body more or less parallel with the skin surface, and with the tarsi of its three pairs of legs lying very close to the skin surface in a symmetrical manner. The antennae are extended upwards and outwards, and the two maxillary palpi extended downwards and more or less touching the skin.

Table 1.—Biting sites of wild *Aëdes trivittatus* on the observer's body.

DATE	FORE LIMB	ANKLE AREA	HEAD BEHIND EARS	FACE OVER BETWEEN EYEBROWS	TOTAL NUMBER OF INDIVIDUALS
7/11	29	2	5	4	40
7/12	25	1	4	6	36
7/16	6	—	2	3	11
7/17	3	—	2	3	8
7/18	2	—	3	—	5
7/25	13	—	5	6	24
7/28	50	2	10	12	74
8/29	30	1	10	10	51
7/30	35	—	12	9	56
8/1	60	5	11	10	87

Mites on Aëdes trivittatus.—During July, 1947, it was noticed that as high as 20 per cent of the adults caught daily from the field for oviposition purposes were infested by a small red mite belonging to the Hydracarina. As many as 15 mites were counted from one adult mosquito female. These mites were usually found clinging to the ventral surface of the mosquito thorax at the insertion of the coxae of the legs to the thorax. It was noticed that the infested adults either gave no eggs at all, or the eggs deposited were very much reduced in number as compared to the number given by non-parasitized adults. It was noticed also that the adults most abundantly parasitized did not die any sooner than unparasitized individuals which served as checks. Those adults which carried mites did not seem to be inconvenienced in their activity.

Most probably the reduction in the number of eggs deposited by these parasitized adults, was due to the deprivation of nourishment of these adults by the mites as a result of which the eggs inside the ovaries failed to complete their development.

SUMMARY.—*Aëdes trivittatus* (Coquillett) breeds in open sites where temporary pools are likely to be formed by rain or flood. It passes the winter in the egg stage and adults make their appearance in the field during the first week of June *A. vexans* and *Psorophora ferox* are most always associated with *A. trivittatus* wherever the latter is found in its breeding sites.

Under laboratory conditions, with a temparature of about 80° F., the minimum period from hatching of the egg to the adult emergence was 6 days and the maximum was 10 days. Under natural conditions the minimum period from hatching of the eggs to the first emergence of the adult was 8 days. In nature, males usually precede the females in emergence and are of shorter longevity.

The larvae of a mite belonging to the Hydracarina was found to infest the adults of this species in nature. As many as 15 mites were counted from one adult mosquito female. The infested adult females either produced no eggs at all, or the number of eggs oviposited were very much reduced in number as compared to the number of eggs given by non-parasitized adults. Adults which carried mites did not seem to be inconvenienced by them and they lived as long as unparasitized individuals.

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DDT and Other Synthetics for Control of Gladiolus Thrips

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The gladiolus thrips, *Taeniothrips simplex* (Mor.), continues to be the most serious insect pest of gladiolus. It is a constant threat to the gladiolus flower crop, and many commercial and amateur growers realize the necessity for using control measures on the growing crop as well as on the stored corms.

Sprays containing paris green and brown sugar were the first recommended control measures for the gladiolus thrips on gladiolus in the field (Dustan 1932), but they were objectionable because they caused foliage injury. Mixtures of tartar emetic and sugar replaced the paris green combinations, because they gave good control of the thrips and were not injurious to the foliage (Nelson 1938, Johnson & Smith 1940). Experiments in 1943 with the first available samples of DDT showed that this material was approximately equal in effectiveness to tartar emetic and sugar (Smith 1944). Friend & Pasfield (1945), in Australia, reported similar results with a 1 per cent DDT dust. As improved formulations of DDT became available after the close of the war, gladiolus growers began using dusts and sprays containing DDT in advance of experimental evidence as to the one most suitable for this crop.

Preliminary experiments with various formulations of DDT and benzene hexachloride in 1946 indicated that the commercially available dusts and sprays of both insecticides were suitable on gladiolus (Smith & Boswell 1947). Dusts and wettable-powder sprays are now recommended (Grove 1947), but may leave unsightly residue on the flowers (Ryan 1947) or cause petal injury (Magie 1947).

Early recommendations for corm treatments included soaking in mercuric chloride solution or fumigation with calcium cyanide or naphthalene flakes (Smith & Richardson 1933). More recently soaking in a commerical preparation containing cresylic acid has been recommended (Creager 1944, Dustan 1947). Farrar (1945) first reported favorable results with DDT on infested corms in bags.

The present paper reports on the 1947 results (1) of field tests with dusts, sprays, and an aerosol containing DDT and several new synthetic compounds and (2) of storage tests to determine the time and method of applying DDT dusts to protect the corms in bags and trays.

PROCEDURE.—In the field tests 50 corms per plot of the variety La Paloma were planted on June 2, in 95 single-row plots 8 feet long, with 12 feet between the dust plots and 8 feet between the spray plots. The young plants were infested with thrips on June 20 by laying foliage of two infested plants in each plot. Six weekly applications of insecticide were made beginning July 2 and ending August 4. The dusts were applied at an average rate of 45 pounds per acre by means of rotary dusters and the sprays at an average rate of 130 gallons per acre by means of knapsack sprayers. The aerosol was applied by means of the knapsack applicator of the type used in greenhouses, except that a 3-gallon-per-hour nozzle was used. In order to determine the effect of delayed applications, benzene hexachloride dusts were applied beginning after the flower spikes appeared.

The diluent for dusts was kaolin. The aerosol contained 5 per cent each of DDT, cyclohexanone, and methylated naphthalenes, 35 per cent of acetone, and 50 per cent of methyl chloride. The emulsions contained 0.5 pound of active ingredient, 0.95 pints of methylated naphthalene, and 1.5 tablespoonfuls of polyethylene glycol monoisooctyl phenyl ether in 100 gallons of spray.

The first flowers were cut on July 22 and the last on September 12. The efficiency of the insedticide was based on the condition of flowers when cut—whether uninjured by thrips, slightly injured, or severely injured.

The storage tests with DDT dust were planned to determine the time and frequency of application and the thoroughness with which the corms should be coated to give good protection from thrips attack during the storage season. Corms for the experiment were dug on October 20 and stored at a temperature between

[1] A. L. Boswell assisted in the work of this project.

50° and 60° F., except during short cold periods, when it dropped to 35°. A comparison was made of applications made on October 31 after the newly harvested corms had dried off slightly, on February 12 after the corms had been cleaned, and on March 17 when the corms had become well infested with thrips. In some tests heavily infested corms were mixed in the trays or bags to insure an abundance of thrips and to check on the transfer of thrips to uninfested corms. One-half ounce of 5 per cent DDT dust was applied with a hand duster to each tray holding about 1 bushel of corms. Applications in one layer over the top of the corms in a full tray were compared with applications in two layers, one half over the corms in the partially filled trays and the remainder over the top. The trays were stacked to simulate commercial storage conditions. In the tests with paper bags, 1 teaspoonful of the dust and 100 corms were put into each bag, the bag was thoroughly shaken, and the top folded over. All tests were made in triplicate.

Table 1.—Results of tests with dusts and an aerosol in controlling the gladiolus thrips.

Material Applied	Thrips—Uninjured Flowers		Clean Flowers		
	Slight	Severe	To Aug. 18	After Aug. 18	Season Total
	Number		*Per Cent*		*Number*
Untreated check	51	229	4.1	10.9	16
DDT:					
5%	51	22	82.4	36.8	223
1% dust plus methylated naphthalene 2%	82	76	53.2	19.1	130
5% in aerosol	32	17	95.9	45.9	248
Benzene hexachloride dust containing 1% of gamma isomer	34	35	87.3	32.3	193
Parathion 0.5% dust	57	33	82.5	34.5	202
Chlorinated camphene 5% dust	38	35	98.7	32.8	233
Difference required for significance at 5% level					52.5

RESULTS IN PREVENTING FLOWER INJURY.—The efficiency of the insecticides was based on the number of clean flowers produced (table 1). Of the five dusts and one aerosol, applied to five replicated plots, the dust containing 1 per cent of DDT, which had been dissolved in methylated naphthalene before mixing, was inferior to all others. The benzene hexachloride dust was inferior to the DDT aerosol. The dusts containing 5 per cent of DDT, benzene hexachloride, 1 per cent gamma isomer), parathion and chlorinated camphene were similar in efficiency.

Of the nine sprays tested on six replicated plots in an adjacent field, all except hexaethyl tetraphosphate resulted in a higher percentage of clean flowers than the standard tartar emetic-sugar spray (table 2). Analysis of the data indicated that differences between the various treatments were not significant. As will be noted from tables 1 and 2, the thrips damage in check plots resulted in almost complete loss of flowers.

All plots showed an increase in the proportion of thrips-injured flowers beginning 2 weeks after the last application of insecticides. On August 18, 80 to 87 per cent of the flowers had been harvested. The percentages of clean flowers cut before and after this date are given in the tables. No injury to flowers or foliage resulted from application of any of these materials except the DDT aerosol. Heavy deposits from the spray jet caused slight bronzing of some leaves.

The first flowers cut, on July 22, had the protection of only three applications of spray or dust; yet the percentage of thrips-injured flowers was no higher than among flowers cut during the next 3 weeks

after the fourth to sixth applications. However, the early applications were made before the flowers spikes appeared. In a test with 1 per cent gama-benzene hexachloride dust the first of three weekly applications made after flower spikes appeared was ineffective against a heavy thrips population. Heavy applications of the dust were made to duplicate plots on August 4, 11, and 18, and the flowers were cut between August 8 and 25. Only 5 per cent fewer flowers were injured in the plications, the second after the corms had been cleaned and returned to the trays on February 12. Apparently sufficient residue adhered to the corms during the cleaning process to give protection throughout the season.

In the trays and bags treated for the first time on February 12, when a light but scattered infestation was present, the corms were protected from further infestation and, except on two corms, the thrips already established had died. This

Table 2.—Results of tests with sprays in controlling the gladiolus thrips.

Materials Applied (Quantities per 100 Gal. of Water)	Thrips—Injured Flowers		Clean Flowers		
	Slight	Severe	To Aug. 18	After Aug. 18	Season Total[1]
	Number		*Per Cent*		*Number*
Untreated check	27	318	0	2	1
Tartar emetic 2 lb., sugar 4 lb.	73	57	80	17	229
DDT in 50% wettable powder: 1 lb.	43	27	89	36	233
2 lb.	45	25	91	31	285
DDT in emulsion 0.5 lb.	58	33	86	24	294
Benzene hexachloride in wettable powder, 0.2 lb. of gamma isomer	52	31	86	30	266
Benzene hexachloride in emulsion, 0.1 lb. of gamma isomer	26	17	95	49	312
Chlordan in emulsion 0.5 lb.	28	24	94	31	306
Chlorinated camphene in emulsion 0.5 lb.	41	25	90	47	284
Hexaethyl tetraphosphate mixture 1 pt.[2]	69	47	75	31	244

[1] No significant differences by the F test.
[2] Commercial product containing 50 per cent of hexaethyl tetraphosphate.

treated plots than in the untreated check plot. Although large numbers of thrips were killed in the unfolding flower parts, survivors in young buds continued the injury. Benzene hexachloride in these tests on La Paloma was less effective than on the variety Mother MaCree as reported by Brooks and Anderson (1947).

RESULTS OF CORM TREATMENTS.—The results of the treatment of corms with DDT dust are given in table 3. On corms treated early in the season most of the dead thrips were found among the outer scales, where they had apparently been killed before they had reached the living corm tissue. On corms treated in February or March and on which feeding was extensive, the thrips were found at the base of the scales, where they had either survived or died apparently from starvation.

One application of dust shortly after harvest (October 31) appeared to give protection equal to that given by two applications, the second after the corms had been cleaned and returned to the trays on February 12. Apparently sufficient residue adhered to the corms during the cleaning process to give protection throughout the season.

In the trays and bags treated for the first time on February 12, when a light but scattered infestation was present, the corms were protected from further infestation and, except on two corms, the thrips already established had died. This protection was also evident where heavily infested corms of another variety were intermixed in the trays on February 12, at the time of treatment. It will be noted from table 3 that a few thrips survived on these treated corms for over two months —an indication that the DDT does not have a fumigating action. It will also be noted that, once the thrips gain entrance to the corm between the scales at the cut-off neck, they may not leave until the food has been exhausted.

The third group of corms in trays and bags were treated on March 17, after having become thoroughly infested with thrips from other corms intermixed with them on February 12. When they were examined on April 20, at least half the surface on practically all corms in the trays had been injured, and the number of surviving thrips was high. The greater number of uninfested and uninjured corms in the bags suggested that the

thorough covering of dust protected these corms from late invaders to a greater degree than the corms in the trays were protected.

DISCUSSION.—The field tests with dusts, sprays, and an aerosol indicate that several of the new synthetic compounds show toxicity to thrips equal to or exceeding that of tartar emetic-sugar sprays. The low effectiveness of hexaethyl tetraphosphate was apparently due to its lack of residual toxicity. An impregnated dust containing 1 per cent of DDT was considerably less effective than a mechanically mixed dust containing 5 per cent of DDT. In greenhouse tests with mechanically mixed dusts containing 1 and 3 per cent of DDT, the control of both onion thrips, *Thrips tabaci* Lind. and gladiolus thrips was less than with a 5 per cent DDT dust. Dustan (1947) indicated that a 3 per cent DDT dust gave medicore results in Canada.

The freedom of thrips injury on the earliest opening flowers, those receiving fewer than six weekly applications, suggested that the first field treatments might be delayed somewhat over the time formerly recommended. However, evidence obtained with a benzene hexachloride dust indicated that applications could not be delayed until flower spikes appeared. Because both sprays and dusts had lost their residual toxicity in less than two weeks, it was evident that the schedule of weekly applications should be maintained.

The tests with the DDT aerosol, made with the applicator as used in greenhouses, indicated that this method would be practical in the small garden.

The experiments with DDT dust on stored corms showed that early-season treatments are important in preventing thrips attack. The satisfactory control obtained with dusts applied to the surface corms of filled trays indicated that this method would be practical in commercial storage houses. Dust in treated trays worked down among the corms as they were lifted or moved, making it unneces-

Table 3.—Control of thrips on gladiolus corms by DDT dust during storage season 1946–7. (100 corms examined from each tray or bag.)

TREATMENT	CORMS		THRIPS PRESENT APR. 20, 1947		CORMS WITH NO FEEDING INJURY	CORMS WITH SEVERE FEEDING INJURY
	Infested	With living thrips	Dead	Alive		
Natural Infestation						
Trays:						
Dusted over top:						
October 31	32	0	44	0	100	0
October 31 and February 12	19	0	25	0	100	0
February 12	50	2	82	4	79	3
Dusted middle and top, February 12	28	0	40	0	82	1
Undusted	97	97	232	673	2	96
Clean and Infested Corms Mixed and Treated February 12						
Trays:						
Dusted over top	66	0	190	0	92	1
Dusted middle and top	56	10	122	14	89	3
Undusted	98	96	216	861	0	92
Bags:						
Dusted	77	0	185	0	87	3
Undusted	90	5	316	5	0	90
Clean and Infested Corms Mixed February 12 and Treated March 17						
Trays:						
Dusted over top	100	0	340	0	0	96
Dusted middle and top	100	20	433	41	0	99
Undusted	100	1	689	21	0	100
Bags:						
Dusted	74	0	190	0	26	40
Undusted	100	100	231	612	1	95

sary to coat each corm thoroughly. As the thrips move about among the corms before the scales dry, the chances for their coming in contact with the dust are increased. If treatment is delayed too long, one of the previously recommended dips or fumigants is necessary to free the corms of thrips before planting.

SUMMARY.—Experiments were conducted in 1947 with the gladiolus thrips, *Taeniothrips simplex* (Mor.), on small field plots of gladiolus to compare with tartar emetic-sugar sprays the effectiveness of DDT and several of the newer synthetic organic insecticides in five dusts, one aerosol, and eight sprays. After six weekly applications of each insecticide, a large proportion of the flowers were free of thrips injury for two weeks but a lower percentage of the later flowers were clean.

In an experiment with dusts from 82 to 90 per cent of clean flowers were cut from plots treated with dusts containing 5 per cent of DDT, 1 per cent of gamma-benzene hexachloride, 0.5 per cent of parathion, or 5 per cent of chlorinated camphene. A 1-per cent DDT-impregnated dust gave 53 per cent of clean flowers. In untreated checks 4 per cent of flowers were clean. In DDT aerosol-treated plots 96 per cent of the flowers were clean.

In an experiment with these materials applied as sprays 86 to 95 per cent of clean flowers were cut from plots sprayed with 1 or 2 pounds of DDT in wettable powder or with emulsions containing 0.5 pound of DDT, chlordan, or chlorinated camphene or 0.1 pound of gamma-benzene hexachloride (all quantities per 100 gal.). Plots sprayed with hexaethyltetraphosphate and tartar emetic produced 75 and 80 per cent of clean flowers, respectively, while the check plots produced no clean flowers.

In tests with 5 per cent DDT dust applied to stored corms, a surface application of 0.5 ounce to 1 bushel of corms in a tray shortly after harvest gave protection from thrips attack throughout the winter. Applications in midwinter before the infestation became severe also gave good protection, but some thrips survived until spring. Applications in March, when the thrips population had increased, were less effective, since the thrips had become established on the corms beneath the scales.

Control of thrips by applications of dust to the surface layer after the trays were filled was equal to that obtained by more thorough distribution of the dust in trays or by shaking corms and dust in bags. DDT did not act as a fumigant against the thrips beneath the scales, and one of the dips of fumigants should be used for a more complete cleanup before planting.

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The Effect of DDT Dusting on Honeybees

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The production of alfalfa seed involves proper cultural practices, pollination, and insect control, and for the most successful seed production these three factors must be coordinated. DDT dust has been shown to provide efficient control for lygus bugs, the most important pest of alfalfa seed in California (Smith & Michelbacher 1946). However, investigations (Linsley 1946a; Linsley & MacSwain 1947b) which were made in conjunction with the development of the lygus bug control program, have shown that DDT dusting of blooming alfalfa has resulted in marked decreases in the populations of honeybees visiting the fields. The populations studied usually regained their previous density within a 3 or 4-day period and when lygus bug control was effective ultimately reached a higher level than prior to dusting. This population decline and recovery has been interpreted as either a repellent action of DDT on the bees or the replacement of killed bees by immigration, or both. The lack of a broad study in which field and colony aspects were closely integrated has delayed a final explanation.

Considerable literature concerning the effects of DDT on honeybees has accumulated. However, most of this involves laboratory or cage studies and is merely indicative of the problem. This literature has been reviewed elsewhere by Roark & McIndoo (1944, 1946, 1947), Knowlton (1948), and McGregor & Vorhies (1947). Of particular interest is the last mentioned paper which reports observations made at the hive on the effects on honeybees of dusting cotton with DDT. The authors concluded that the commercial dusting of cotton which was under their observation was not hazardous to commercial beekeeping. They question the repellency of DDT and point out that honeybees can recover from rather conspicuous DDT effects.

PLANT OF EXPERIMENT.—An experimental area was selected in the northwest portion of the Palo Verde Valley, 2.5 miles from Blythe. In this area the supply of available nectar and pollen, other than alfalfa, was comparatively low, and there was but a single small apiary within each flight range of the alfalfa fields. The area contained one alfalfa seed field (Field A) at the beginning of the experimental period, and subsequently a second field (Field B) was allowed to go to seed. Field A was an 8-year old 35-acre field from which one cutting of alfalfa hay was taken in the spring of 1947 before it was allowed to go to seed. It was irrigated three times (May 1, May 17, June 7) during the development of the seed crop. These frequent irrigations caused it to bloom for a longer period of time than would ordinarily be expected. Field B was an 8-acre field on very sandy soil from which hay was cut twice before allowing it to go to seed. In spite of several irrigations the blooming period of this field was short and it dried up rapidly. These two fields were treated several times with 5 per cent DDT dust, and colonies of bees were moved into and out of the area in order to study the possible effects of these dustings on the bees both in the field and at the hive. The experimental apiary of 30 colonies was provided from three large commercial apiaries scattered along the west margin of the valley. The flight range of bees from these commercial apiaries was outside of the experimental area. Ten experimental colonies were secured from each of the three apiaries. These were carefully selected for uniformity and strength as determined by colony weight, previous history, cluster counts, and amount and distribution of brood.

The two experimental fields were dusted by airplane at various times with 5 per cent DDT dust applied at 30 pounds per acre. Field A was dusted in "early bloom" at 4:30 A.M. on May 17, in "full bloom" at 8:00 A.M. on June 14, and in "late bloom" at 4:30 A.M. on June 26. Field B was dusted in "25 per cent bloom" at 8:45 A.M. on June 14, and in "past full bloom" at 4:50 A.M. on June 26. Twelve colonies were moved to the experimental apiary site in the southwest corner of

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Field A prior to the first dusting. The experimental apiary site was partially shaded by willows and with the approach of hot weather the colonies were further protected by extra tops. Additional movements of these and other colonies were made into and out of this location so that various lots of colonies were exposed to each of the dustings, to combinations of the dustings, or to no dusting. The movements were so arranged that each colony was moved into and out of the experimental area only once.

By the use of marking and field counts it was determined not only that most of the bees from the experimental hives were visiting Field A, but that the majority of the bees in this field were from the experimental colonies. The effects of dusting were studied in the field by counts of bee and lygus populations, visual observations, and mortality of field bees held in small cages. The effects at the hives were studied by following changes in weight, pollen collecting activity, flight lanes, size of cluster in early morning, number of dead bees in front of each hive, brood counts, and honey production.

PRELIMINARY MARKING STUDIES.—A series of preliminary laboratory and field tests were conducted at Berkeley to find suitable materials for mass marking of bees in the field. On the basis of these tests it was decided to use titanium dioxide and basic fuchsin.

BEE MARKING AT THE COLONY.—The bees in Field A were marked in two ways —at the colony and in the field. At the colony the bees were sprayed with an alcoholic solution of basic fuchsin (3 grams of basic fushcin per 100 cc. of 95 per cent alcohol). On May 15, seven colonies were marked and on June 12, six were marked. The colony entrances were blocked with shipping screens and the field bees piling up about the entrance to each colony were lightly sprayed with an atomizer. After the spraying, the entrances were opened and bees allowed to enter the hive. This procedure was repeated twice at each spraying. No serious disturbance of the colonies was noted. The method was particularly useful in this experiment because it mainly marked field bees and only slightly interrupted the activity of the colony.

Except for one colony, there was no recognizable effect on colony weights, number of dead bees in front of hives, or flight activity a few hours after marking. In that colony there was a slight increase in the number of dead bees in front of the hive on the following morning as a result of excessive wetting during the spraying operation.

Samples of bees were taken at numerous points within the flight range of the colonies. Bees in each sample were killed in

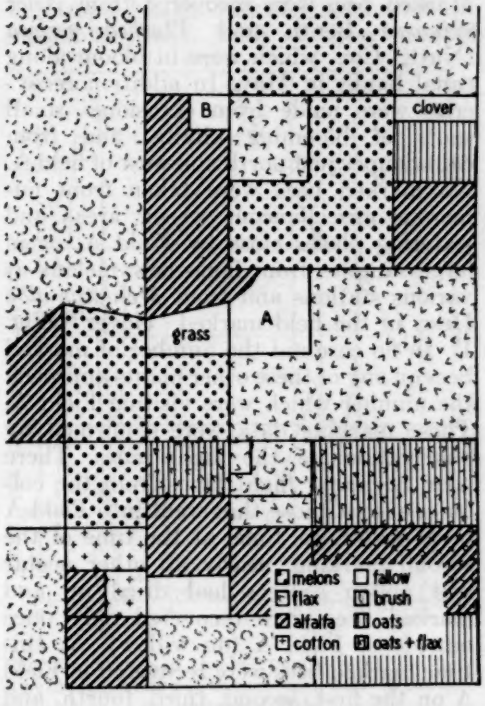

FIG. 1.—Map of experimental area two and one-half miles northwest of Blythe, California. A is a 35-acre alfalfa-seed field.

cyanide and spread out on paper toweling. Alcohol was slowly dropped onto the bees and traces of red which appeared on the paper revealed the marked specimens.[1] In most cases, when a marked bee was washed with alcohol the dye became very conspicuous. Bees so marked were recovered in and about Field A. In May, marked bees were recovered in Field A on the day of marking and on the first, second, third, and fifth days after dusting. In some cases over 10 per cent of the bees sampled in the field were marked. This percentage of recovery in the field was

[1] A similar marking method has been developed previously for mosquitoes (Zetek 1913) and flies (Parker 1916).

roughly the same as the estimate of field force marked at the hive, *i.e.*, 7 to 10 per cent. The percentage of recovery before dusting (7.4 to 10 per cent) was essentially the same as after dusting (7.6 to 9.5 per cent).

This marking method also provided some indication of the amount of pollen and nectar competition in the area for it indicated what flowers these bees were visiting and their relative importance. Marked bees were recovered from *Aster spinosus* Benth and *Pluchea sericea* (Nutt.) Cov. which were in bloom along canal banks in May. In addition recoveries were made from occasional small spots of blooming alfalfa, and from cantaloupes just north and west of field A. No marked bees were taken from numerous miscellaneous weedy areas and watering places close by Field A, or in large samples from honeydew melons at various stations and from *Melilotus alba* Desr. in the field marked "clover" (Fig. 1). In no case did the number of marked bees on any of these other plants approach the number which were visiting Field A. These marking data were confirmed by observations of the flight lanes. There were no major flight lanes from the colonies except those that went into Field A or to water. In June, at the time of the second marking, nearly all other nectar and pollen sources had dried up and marked bees were recovered only once outside of Field A (on willow). At this time marked bees were recovered in Field A on the first, second, third, fourth, and fifth days after marking.

BEE MARKING IN THE FIELD.—In addition to marking bees at the colony, bees were marked in the eastern portion of Field A with a white pigment. As the bees visited the alfalfa flowers, they were sprayed individually with a small hand atomizer containing titanium dioxide and denatured alcohol. On May 15, 1600 bees were marked in this area. Fifteen minute check periods at the hive entrances revealed white-marked bees at the entrances of 7 out of 10 hives. An inspection of the interior of one hive revealed six white-marked bees.

It is felt that the marking data indicate that nectar and pollen competition with Field A was not great, that most of the bees in our experimental colonies were visiting Field A, and conversely, that most of the bees in Field A were from the experimental colonies.

BEE POPULATION TRENDS IN FIELD A.—Both native wild bee and honey bee populations were followed in the two experimental fields throughout the blooming period. However, native wild bee populations were so low as to be insignificant in the experiment. The populations were measured by means of the sweep method as described by Linsley (1946b). All population samples were taken in 10-sweep counts at a series of stations throughout the field. Both nectar-gathering and pollen-gathering honey bees were included in the counts. Two daily counts were made at each of 20 stations in Field A, the first between 9 A.M. and 10 A.M. and the second between 3 and 4:30 P.M. The morning counts were found to give the best population data as they were less affected by temperature, humidity, wind, and nectar flow than were the afternoon counts. However, the afternoon counts, especially early in the season when other flowers provided pollen competition, yielded a higher percentage of pollen-collecting honeybees. The trends of the lygus bug population were also followed during this same period. The results of the morning counts for the eastern portion of field A are shown in figure 2 for the period covering the first two dustings.

A characteristic feature of the bee population curve, as was found in previous seasons, was the pronounced decrease in number of bees just after dustings and the recovery of the population level in a few days. This temporary decrease (Fig. 2) does not seem to interfere with the normal trend of the curve. The decrease must be interpreted either as repellency or as mortality followed by replacement in a few days by new bees. In the latter case it would have to be further postulated that the replacement always involved the proper number of bees to permit resumption of the prior population trend. Further, the observed population increase cannot be explained on the basis of new colonies coming into the area since there were no movements of colonies until after the population in the field had either retained or surpassed the pre-dusting level. In the course of these experiments the population trend probably did not reflect saturation of the field by bees. Since, as has been shown above, most of the bees

in the field were from the experimental apiary and most of the bees from the apiary were visiting this field, it would seem that the population curve may be properly interpreted as an expression of the flight from the experimental colonies. Since figure 2, which is typical of the population curves reported previously (Linsley 1946a; Linsley & MacSwain 1947b), cannot be satisfactorily explained on the basis of bee mortality, it may be interpreted as probably reflecting a repellent effect of the DDT on the honeybee population. Such an effect might not be unexpected since such widely different chemicals as nicotine, lime sulfur, sulfur, sulfur-pyrethrum, creosote, carbolic acid, and copper sulfate are repellent to bees (Knowlton 1944; Butler *et al.* 1943; von Dehn 1942; Vansell & Todd 1946). McGregor & Vorhies (1947), on the other hand, have interpreted their data as giving no indication of repellency, although they did observe a similar decrease in the field populations for 1 or 2 days following dusting of cotton fields.

Linsley & MacSwain (1947b) in considering arguments in favor of repellency as an explanation of changes in the bee population have pointed out that "there is almost invariably a rise in the population in undusted areas coincident with the decrease in dusted sections." To help explain this phenomenon, further studies were conducted in a late blooming field several miles south of the experimental area. The south half of this field was dusted on July 17 with 5 per cent DDT applied at the rate of 30 pounds per acre. This dusting was followed by a marked difference both in alfalfa bloom and in the bee population in the two parts of the field, the dusted portion having approximately three times as many bees as the undusted. On August 1, although the field was in a late-bloom to green-curl stage, 5000 nectar and pollen gathering honeybees were marked as described above with the white pigment in a restricted portion of the undusted north section of the field. A late evening collection of bees from this marking area on the same day revealed only one marked bee in a sample of 98 individuals. The undusted north half of the field in which the bees had been marked was dusted at 5:30 A.M. on August 2 with 5 per cent DDT at the rate of 30 pounds per acre. The bee population showed the characteristic decrease in the dusted half, but there was no apparent increase on the south half. This was probably because of the great difference in population size of the two halves. A collection of 538 bees taken in sweeps evenly distributed through the field on the morning of the day of the second dusting contained 21 marked bees, of which 14 were in the area in which they had been marked, and only 2 in the undusted sections (the south half was treated as an undusted area after the second dusting). Both of these marked

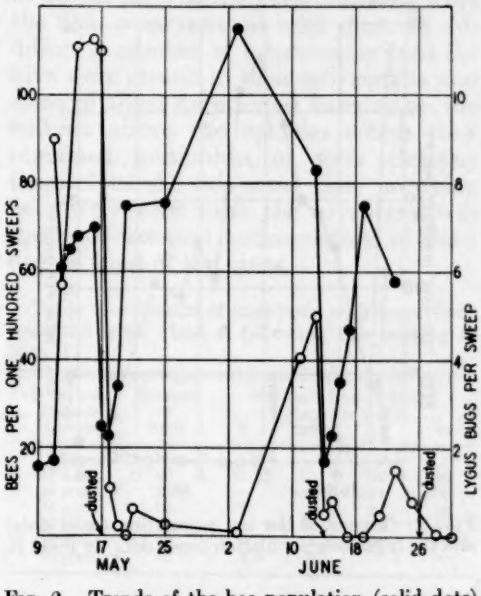

FIG. 2.—Trends of the bee population (solid dots) and the lygus bug population (open dots) in the eastern portion of Field A.

bees were taken just outside the dusted area. A similar collection was made between 4:55 and 6:25 P.M. on the same day and of a total of 775 bees there were 12 marked individuals of which 9 were in the dusted area (2 in the area where originally marked) and 3 scattered in the undusted area. The next morning a sample of 623 bees contained only 7 marked specimens, 6 in the dusted area (4 in the area where originally marked) and only 1 in the middle of the undusted area. No further counts could be made until August 6 at which time in a small sample of 151 bees no marked individuals were recovered. In prior recoveries both nectar and pollen-gathering honeybees were found in both the dusted and the undusted sections of the field.

On the basis of the data just presented there is no evidence to show that this distribution is anything more than normal dispersal or that it may not have been due to disturbance of the bees in the application of the pigment. However, the literature on honeybee flight habits would indicate that under normal conditions the bees which were already oriented to a particular part of the field would continue to work it as long as there was nectar and pollen available. This may be essentially the picture shown by the morning counts

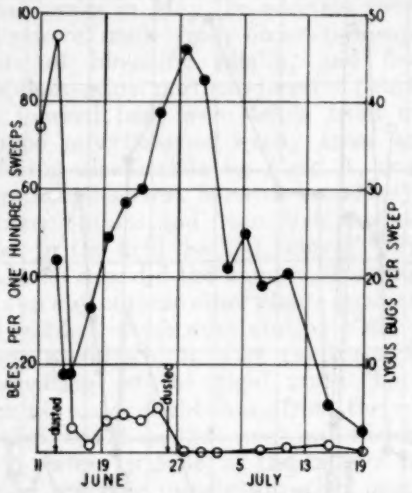

FIG. 3.—Trends of the bee population (solid dots) and the lygus bug population (open dots) in Field B.

of August 2 in which 14 bees, or 66 per cent of the marked bees recovered in the dusted area, were in the immediate area where they had been marked originally. The seven other bees recovered in the dusted area were all in the region which bordered on that in which the bees had been marked. In the afternoon sample the increase in per cent of bees outside of the original marking area might possibly be a further indication of a repellent action. However, because of the small numbers of marked bees recovered and the large population in the undusted area, it can only be concluded that the information from this experiment is merely suggestive and certainly not clear evidence of a repellent action.

The abrupt fall in the population curve of honeybees in Field A (Fig. 2) following the early morning dusting on May 17 is somewhat less severe than that following the late dusting on June 14. In addition the population recovered its previous level 3 days after the early dusting while recovery following the late dusting took 5 days. These small differences may not be significant or may reflect factors other than time of application. However, this population curve also gives further evidence that the bees in Field A were largely from the experimental apiary since the first two counts made prior to moving of additional bees into the area averaged 16 and 17 per hundred sweeps, respectively, while four counts taken after bees were moved in averaged between 60 and 70 per hundred sweeps.

LYGUS BUG POPULATION TRENDS IN FIELD A.—Lygus bug control was very effective in this field and this also had an effect on the bee population. At the time of the first dusting a high percentage of the potential bloom in the field was being blasted and the bee population was leveling off. As a result of reduction of lygus bugs from 11.3 per sweep to none the amount of available bloom increased rapidly and the total bee population of the field increased by 50 per cent. During the period of heaviest bloom the lygus bug population was very low and the bee population very high. The rise in the lygus bug population in early June was due to migration resulting from the cutting of alfalfa fields to the northwest. The commercial value of the later dustings is questionable and they were made for the purposes of the bee study. At the time of the second dusting the field had begun to dry and, although somewhat revived by late irrigation, the bloom declined. This second dusting was too late for any appreciable increase in the total bloom, but it probably allowed bee activity to continue over a longer period than would have been possible otherwise.

In the west portion of Field A, the bee population, which was very low prior to the first dusting because of severe lygus injury, increased 7-fold following dusting. The second dusting effect was very similar to that in the eastern portion of the field. The afternoon counts for these two areas gave similar general results but were complicated by wind, excessive temperature, and humidity.

POPULATION TRENDS IN FIELD B.—Figure 3 gives the trends of the bee and lygus bug populations in Field B. The

situation in this field, where only a few of the bees were from our experimental apiary, was very similar to that in Field A. The lygus bug population was very much higher and its effect was evident much sooner. Since this field dried up rather rapidly the decline in bee population during early July was also rapid. During this period the population decline was further accentuated because several alfalfa hay fields to the south were in bloom and attracted the bees. The characteristic break in the curve is evident following the June 14 dusting, but no break is shown following the June 26 dusting because apparently the population recovered before the count on June 28 was obtained.

Field Mortality Tests.—A series of over 50 cage tests, measuring the per cent of mortality in samples of 10 field bees each, taken at various times after dusting, gave approximately the same results as those reported by Linsley & MacSwain(1947b). McGregor & Vorhies (1947) obtained a somewhat similar result by placing caged bees in cotton fields before dusting. In the present tests the per cent mortality increased with time on the day of dusting and for any particular day, but decreased rapidly with each consecutive day following the day of dusting. The results obtained with the first dusting in Field A are shown in table 1. The 24-hour readings would appear to be the best comparative reading as frequently the checks have appreciable mortality at 48 hours. Similar results were obtained for the two other dustings in both fields studied.

Mortality in these cage tests, as has been discussed previously (Linsley & MacSwain 1946b), is a rather strong argument against repellent action of DDT. General field observations on the activity of the honeybees in recently dusted fields, where "sick" or abnormally behaving bees are common, have suggested that these cage tests are a reflection of actual mortality. On the other hand, since the post-dusting population is abnormal and since bees do recover from similar effects of DDT (McGregor & Vorhies, 1947), it will be necessary to have some other method of evaluating cage tests. A possible interpretation of the apparent difference in mortality between field condition and cage condition might be found in the results of Häfliger (1948). He has shown a remarkable correlation between temperature and the susceptibility of bees to DDT. At 36° C. (more or less comparable to our field temperatures) DDT has a far weaker insecticidal action than at 20° C. (more or less comparable to our cage conditions which averaged 21 to 27° C.). This may also explain area differences in the effect of DDT on bees.

OBSERVATIONS AT THE HIVE.—At the time of the late dusting of Field A, which was made when the bees were active in the field, it was observed that from 10 to 30 per cent of the bees returning from the field were covered with dust. In addition, a number of bees coming into the hive were erratic in their movements and some of them were found hanging on the willows above the colonies where they remained motionless or were cleaning themselves. At this same time no dying bees were seen near the hives nor was there an unuaual accumulation of dead bees in front of the hives.

Table 1.—Results of cage tests with honeybees collected from Field A following the dusting of May 17.

DATE AND TIME OF COUNT	NUMBER OF BEES	PER CENT BEES DEAD IN INDICATED HOURS			
		8	12	24	48
May					
17 a.m.	20	75	85	90	90
17 p.m.	20	—	100	100	100
18 a.m.	20	0	5	10	10
18 p.m.	20	—	35	35	45
19 p.m.	40	0	12.5	20	22.5
20 p.m.	40	2.5	5	7.5	—

Because it has been claimed that large accumulations of dead bees are found in front of hives after DDT dustings, a particular effort was made to confirm this observation. A sand-covered area 4 feet square was prepared directly in front of each hive and the number of dead bees accumulating on this plot was counted throughout the period of the experiments. Although many of the dead bees were carried some distance from the hive this area was undoubtedly a comparative index to the number of dead bees removed. At no time during the course of the experiment were any unusual collections of dead bees noted. The average number of dead bees in front of the colonies declined from 32 to 14 during the period before the first dusting. For the 3 days after dusting there were approximately 54 dead bees per colony per day. The later counts were somewhat complicated by hot weather

and the throwing out of drones. This latter fact may be an indication of increased bee mortality, or may have been due to the cutting off of the nectar supply when the bees were driven from the field. However, it is more likely that it was due to the increased temperatures since it was accentuated later in the season. In the case of the late morning dustings, counts made during the week following dusting were lower than those which had been taken on the days prior to dusting. Adverse weather conditions were observed to have a far greater effect on the number of dead

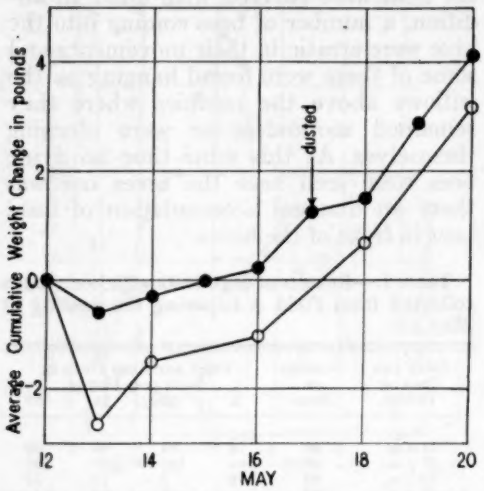

FIG. 4.—Effect of the May 17 dusting on twelve treated colonies (solid dots) as compared to six colonies not exposed to dusting (open dots).

bees in front of the hive than did the dustings. The extremely high temperatures in this area caused the honey flow to cease on several occasions and much of the field force transferred its activities to water gathering. Such conditions were also instrumental in bringing about periods of low honey production and small weight gains.

COLONY WEIGHTS.—The portion of the data dealing with weight gains of the individual hives gave excellent quantitative information on hive activity. The weights were taken to the nearest ounce. Although occasionally weighing was not completed until 7:00 A.M., it was usually carried out between 4 and 6 o'clock in the morning. In this area there was frequently a small flight at 5:30 A.M. but weights on a series of 12 hives showed an average loss per colony of only one quarter of a pound from 4:15 A.M. to 5:45 A.M.

The hive weights varied with changes in temperature, humidity, amount of wind, nectar flow, brood counts, colony movements, time of day, and the use of the pollen traps. All factors except dusting were as comparable as possible. The check apiary was about 4 miles air-line from the southwest of Field A. Check colonies were either held at this apiary or brought to Field A after the dustings. There were no dustings in the vicinity of the check apiary but forage conditions were slightly inferior in June. Brood counts and the movements of colonies were timed so that their effect was completely overcome prior to dust applications. All colonies, both checks and treated, were moved just twice, once to Field A and once out to the check apiary. Pollen traps were run intermittently on equal proportions of the colonies exposed to dusting and those held as checks. The pollen traps were placed permanently on the colonies so that the bees were accustomed to them and the screens were dropped for short periods (usually of a few hours duration) to obtain pollen samples. This use of the pollen traps was found to have a negligible effect on the cumulative weight gain of the colonies.

Figure 4 gives the average cumulative weight changes in pounds for the 12 colonies subjected to the first DDT dusting and for the 6 check colonies held outside of the experimental area. After an initial loss (apparently due to robbing during one of the brood counts) the curve for the treated colonies closely followed that of the check colonies. The nectar flow in the check area was essentially the same as in the experimental area at the time of this dusting. The most significant feature of this curve is the small but definite decrease in the trend of weight gains of the dusted colonies as compared to the checks following dusting. This is probably in direct correlation with the decrease in the bee population found in the alfalfa field following dusting. The resumption of weight increase immediately would also seem to be correlated with the recovery of the population in the field. It does not seem possible that recovery could be so rapid if the decrease was due to mortality of the field force.

A similar decrease was observed at the

time of each of the three dustings. Figure 5 illustrates the weight changes at the time of the second dusting on June 14. The six check colonies were moved out 2 days before dusting, and the break in the check curve before dusting is due to this movement. The variations in this check curve are due to high temperatures in early morning and consequent flights before weights could be obtained in the check apiary. The first weighings were always made in Field A. The second check curve represents six additional check colonies which were moved into the experimental area after the dusting.

The colonies were extracted on July 11. For uniformity, one beekeeper made all extractions. Because of the small number of colonies and the differences between the check and the experimental areas during late June and early July, comparisons were difficult to make but, in general, the colonies which had been exposed to the most dustings produced the most honey. On the other hand, the colonies which were subjected to the greatest number of dustings were the ones which were in the area with the heavier honey flow.

POLLEN-COLLECTING ACTIVITY.—Pollen traps were used on 12 of the experimental colonies. These traps were similar to those used by other workers (Todd & Bishop 1940; Hare & Vansell 1946) except that the trap was deeper to allow for additional ventilators, the landing board was of wood instead of hardware cloth, and the pollen-removing screen consisted of a single thickness of hardware cloth instead of a double-walled barrier. Double-walled screens made it impossible to take 2-hour checks because of disturbance to the colony. They also provided a poorer comparison of pollen income of different colonies because they were harder to standardize. Although the single screen removed a smaller percentage of the incoming pollen than the double screen, eight traps gave an average daily yield of 47.0 grams (dry weight) of pollen on May 16; and 16.4 grams on June 16 as compared with the results of Hare & Vansell (1946) in a somewhat similar situation at Delta, Utah, where the daily average of traps with double-walled screens over a 22-day period (July 31 to August 21) was 15.9 grams. On the basis of visual counts of pollen removed from entering bees, it is estimated that only about 10 per cent of the pollen was removed by the single screen.

The pollen traps remained under the colonies constantly and the collecting screens were held up so the bees passed under them. When the screens were up, the traps did not interfere with colony activity. The collecting screens were dropped on groups of two hives for each

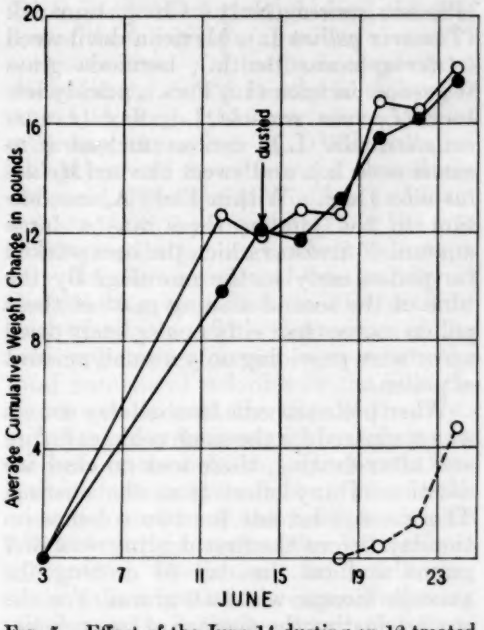

FIG. 5.—Effect of the June 14 dusting on 12 treated colonies (solid dots) as compared to 6 colonies (open dots, solid line) moved out prior to dusting and 6 colonies (open dots, broken line) moved in after the dusting.

2-hour period during the time of bee activity on May 13 to May 15 and again in a similar fashion following dusting on May 18 and 19. In addition, the screens were left down all day and the pollen collected every 2 hours from eight colonies on May 16, the day before the first dusting, on two colonies on May 17, and again on all colonies on May 20. A 4-hour morning sample was taken on all 12 traps on May 25. At the time of the second dusting all traps were left down for a 4-hour morning sample on June 3 and all day on June 12, 16, and 22.

At the time of sampling, the pollen was carefully brushed from the pollen drawer into shell vials which were then plugged with cotton. The total sample was allowed

to dry and was then weighed to a hundredth of a gram. The pollen was then segregated and identified by color from pellets taken from bees on various plants and also by microscopic comparison with a slide collection of all pollen sources in the area. At the time of the first dusting, bees were gathering nectar or pollen, or both, from a number of sources outside of Field A. These sources were mainly willow (*Salix exigua* Nutt.), arrowweed (*Pluchea sericea* (Nutt.) Cov.), tamarisk (*Tamarix gallica* L.), Mexican devil weed (*Aster spinosus* Benth.), bermuda grass (*Cynodon dactylon* (L.) Pers.), prickly lettuce (*Lactuca scariola* L.), flax (*Linum usitatissimum* L.), various melons (*Cucumis melo* L.), and sweet clover (*Melilotus alba* Desr.). Within Field A, in addition to the alfalfa, there was a large amount of *Sonchus* which the bees worked for pollen early in the morning. By the time of the second dusting most of these pollen sources had either completely dried up or were providing only a small amount of pollen.

When pollen income from all-day counts was compared for the same colonies before and after dusting, there was no clear indication of any effect from the dusting. The average income for two colonies on the day before the first dusting was 47.7 grams and on the day of dusting the average income was 60.6 grams. For the second dusting the average of two colonies 2 days before dusting was 11.4 grams and for the same colonies 2 days after dusting was 16.2 grams. Although the pollen-collecting ability of a colony appears to be an excellent method of comparison between hives over a short period of time, the differences in pollen income obtained from the trap studies did not give any indication of a harmful effect due to dusting.

The effect of these pollen traps upon the economy of the hives was apparently both beneficial and detrimental. In the case of the first 18 experimental colonies those with pollen traps averaged 47.98 pounds gain during the experimental period while the six without traps averaged 42.97 pounds. The bees from the colonies on the pollen traps started out earlier in the morning because their landing board was higher off the ground and dried off earlier. It was also observed that fewer bees hung out on the fronts of the hives in the hot afternoons because of the better ventilation provided by the traps. These two factors apparently more than offset any adverse effects from the occasional use of the traps. However, a single colony, which was selected in another apiary and placed on a pollen trap with a single screen down continuously for 6 weeks, gained only 27.12 pounds during this period as compared to 41.86 pounds average for five other colonies in the same apiary.

BROOD COUNTS.—Brood counts were made at the beginning and the close of the experimental period. These counts consisted of removing from the hive every frame containing sealed brood and placing each frame in an open counter having the sides divided vertically and horizontally with wires placed at 1-inch intervals. With this equipment it was possible to count the actual number of square inches of sealed brood in a hive in a few minutes. This type of count has not only been considered a good measure of colony strength but also to have a very minor effect on the total efficiency of the colonies. However, the first brood-count, which was made on May 9, had such a severe effect on the cumulative weight gains of the colonies that no further brood-counts were made on the experimental colonies until the time of extraction. As a check of the adverse effect of this method of handling bees, a colony was selected in another apiary and brood counts were taken four times over a period of 5 weeks on this colony. When the net weight gain of this colony was compared to five additional colonies, it was found to have gained 13.8 pounds less than the average gain of the other five colonies. The colony which was examined four times had a net gain of 28.1 pounds while the five check colonies ranged from 30.8 to 52.8 pounds and averaged 41.9 pounds net gain. In addition, following each brood count there was a definite break in the production curve of the colony examined while all of the check colonies maintained a consistent increase. Another disadvantage of this method is that, taken by itself, it may be misleading. For example, one colony which had 594 square inches of sealed brood on May 9 gave a consistently poor performance although at all times it was well supplied with workers. A fur-

ther difficulty associated with brood counting is the amount of robbing which may take place near the end of the operation, especially a when large number of hives are checked in a single apiary. The results of the brood counts showed no significant differences in amount of brood present in any colony regardless of the number of dustings to which it had been subjected.

CLUSTER COUNTS.—As another possible means of checking the effects of DDT dusting on the honeybee colonies, "cluster counts" were made every second morning for the period covering the first two dustings. In the early morning, before there was any flight from the colonies, the cover of the hive was lifted and an estimate made of the number of frames the bee cluster covered. This method was not satisfactory for several reasons. In the first place, on very warm nights the bees did not cluster; in the second place, all counts had to be made by the same individual, and thirdly, individual colonies varied more between counts than did different colonies. However, there was no indication of decreases in the size of the cluster following dusting.

GENERAL HONEYBEE CONDITIONS.—An attempt was made to follow the condition of all bees in the Palo Verde Valley exposed to dustings throughout the summer. However, this was ultimately abandoned due to the very severe weather conditions which developed. Temperatures during the 1947 season were somewhat higher than those experienced in the 2 previous years. Whereas the average daily maximum for July, in 1945, was 107.1° F. and in 1946, 105.9°; in 1947, it was 109.5°. Similarly, in August and September of 1947, with average daily maximums of 104.9° and 105.1°, respectively, high temperatures not only restricted the normal activity of the bees but probably also contributed to the blossom failure of several native plants. As these native hosts are normally relied upon to supply winter stores for colonies which are extracted in June and July, the majority of the hives in the area went into the winter without their normal supplies. One small apiary in the extreme southern portion of the valley was extracted on July 3 and an average of 30.3 pounds for the 18 colonies was obtained. On August 4, the owner estimated that, on the basis of past history of the area, his colonies should have increased from 20 to 30 pounds each. However, when the hives were weighed on this date the average increase was found to be only 3.9 pounds. This failure to increase in weight was undoubtedly due to the temperature and not to DDT, since the alfalfa seed fields were dusted only once in this area. In midwinter it was reported that the majority of the bees in the valley would have to be fed to carry them through until the first flow of the following season.

DISCUSSION.—On the basis of previous work and the data presented in this paper it would seem that certain questions regarding the effect of DDT dusts on honeybees can now be more completely answered. When an alfalfa field in bloom is dusted with 5 per cent DDT at the rate of 30 pounds per acre, there follows a very definite recession of bee activity in the field as compared to the activity prior to dusting. This depression of the field population occurs even when the total number of colonies in the area remains constant. At the time of the dusting there may be conspicuous effects on the bees in the field and sometimes there is an increase in the number of bees in the undusted portion of the field. A variable but frequently large number of the bees collected in alfalfa seed fields following dusting die when held in cages. Following the depression in the bee population there is a rapid recovery within 3 to 5 days and if lygus control is effective the increased bloom in the field attracts even larger numbers of bees than were present before dusting. Correlated with the dustings there is a small but significant change in weight gain of colonies subjected to dusting as compared with the gain of colonies held as checks in similar but undusted areas. This effect, although definite, is small and recovery is rapid. Other indications of colony activity, such as the number of dead bees in front of the hive, brood counts, cluster counts, pollen traps, seasonal honey yields, and general welfare of the colonies, would indicate that the effect on colonies is still small even when they have been exposed to three dustings.

It would seem clear on consideration of these experiments, that the effects of dusting both in the field and at the hive can hardly be attributed to large scale mortality. If large scale mortality did

occur, the effect on the colony would have been greater than that which was observed. Furthermore, the recovery of the field population would have been slower since other bees were not available for re-population. If any mortality did occur, it must have been very minor and would appear to have been far offset by the increased honey flow.[1] Although the results of the cage tests suggest mortality, it is felt that less significance should be attached to them since the high mortality occurs in samples of reduced abnormal populations in held confinement at temperatures which might be expected to show a greater effect of the DDT than field temperatures.

The major factor which causes fluctuations in the field force and in subsequent hive weights would seem to be some form of repellency which drives a major portion of the bees from the field. This interpretation is supported by rapid recovery of field populations and hive weight gains, increases in bee populations in undusted areas, abnormal bee activity in recently dusted fields, and lack of any other indication of serious bee mortality. The distinct effect on cumulative hive weight gains is probably due to the abandonment of the alfalfa by the field force and a consequent reduction in honey flow into the colonies. It is concluded, therefore, on the basis of this experiment, that if dusting of alfalfa seed is kept to the minimum required for control of lygus bugs, there is no serious hazard to bees and that ultimately both the beekeeper and the seed grower will be benefited. However, since there appeared to be a slightly greater effect on the bees when dusts were applied during the day, it is recommended that applications be made before the bees come into the field.

SUMMARY.—In an area 2 miles square near Blythe, California, containing a limited acreage of pollen and nectar sources and in which the honeybee population was controlled, the effects of DDT dusting on honeybees were carefully studied. Techniques for measuring these effects are discussed. It was shown by marking that most of the bees from the experimental hives were visiting one alfalfa seed field, and also that the majority of the bees in this field were from the experimental colonies. This field was dusted three times with 30 pounds of 5 per cent DDT dust per acre per application. It was demonstrated in this experiment that such dusting of alfalfa in bloom has a detrimental effect on the production and activity of honeybees. Although this effect is definite it is small and is more than offset by the increased nectar flow when lygus bugs are controlled. The marked decline in bee populations in a dusted field immediately after treatment would seem to be largely due to repellent action of DDT dusts. Even though the effect on the bees is not great, dusting of alfalfa in bloom should be restricted to the essential minimum and should only be done in the early morning before the bees are active.

[1] This has been previously suggested by Michelbacher, *et al.*, (1946).

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Blow Fly Control with DDT Sprays Dispersed from Aircraft

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In 1944 the Naval Medical Research Unit No. 2 of the United States Navy submitted a report[2] of experiments conducted with DDT aerial sprays for the control of flies under combat conditions on the island of Peleliu in the Pacific. The major species involved in these experiments was *Chrysomyia megacephala* (Fab.). The investigators repeatedly treated approximately 1200 acres during a 2-weeks period employing 5-and 10-per cent DDT in an oil solution at rates varying from 0.2 to 0.6 lb. of DDT per acre. A total of six treatments were made. The fly population was steadily increasing during this period because of large numbers of enemy cadavers which favored extensive fly breeding. In general the areial treatments proved relatively ineffective, for only 30- to 50-per cent reduction of flies was obtained with each application. Since the larvae and pupae were apparently unaffected, the emerging flies soon replaced those that were killed, and the numbers in a few days surpassed those prior to each treatment.

Because of the failure to control flies with relatively low rates of DDT treatments under conditions mentioned in the report, an experiment was planned in the United States to determine whether satisfactory fly control could be obtained by treating a small part of a large area with a single aerial application of DDT at a dosage high enough to give a residual effect. The experiment was conducted in Texas from April 20 to May 12, 1945. It seems desirable to publish the data obtained, as the results of this experiment are important because much consideration has been given to fly control by the use of aircraft and DDT in connection with poliomyelitis and other fly-borne epidemics.

DESCRIPTION OF TEST AREA.—The area selected was typical range country near Menard, Texas, where several common species of blow flies are known to to occur in large numbers. Blow flies are strong fliers; they may travel 12 to 15 miles, or more in a few days. The vegetation in this area consists of scattered low-growing brush, such as agarita and live oak, and low-growing mesquite and oak trees. The leaves are small and typical of those found in a semiarid area. An abundance of open grassland facilitated getting the spray down to the ground.

[1] The following people assisted in conducting the tests: C. N. Husman, O. M. Longcoy, H. E. Parish, C. S. Rude, and R. W Wells. Determinations of DDT were made by George T. McCollough, Corp., AUS, assigned from Army Air Forces Committee on Aerial Dispersal of Insecticides, located at Army Air Forces Center, Orlando, Florida.

[2] Hurlbut, Herberts (Lt. Comdr.) and Wilson, Charles S. (Lt. jg.). Report of experience with DDT in the control of flies under combat conditions 1944. (Unpublished.) This report which was classified as "secret," was made available to the Orlando, Fla., laboratory of the Bureau of Entomology & Plant Quarantine early in 1945. Permission to refer to this report has been kindly granted by the Navy.

Within this area a 750-acre tract, nearly square in shape, was chosen for treatment. It was divided into three 250-acre plots for application of three different formulations of DDT.

EQUIPMENT, MATERIALS, AND METHODS —The spray equipment, designed by C. N Husman, consisted of a rig mounted beneath the wings of PT-17 (Stearman) airplane. Two centrifugal pumps activated by a small wind-driven propeller forced the liquid through small apertures into a series of small venturis mounted in larger venturis. Provision was made for recirculating a portion of the liquid back into the bottom of the tank to give necessary agitation when suspensions were used.

DDT was tested as an oil solution, an emulsion, and an aqueous suspension. Enough of each formulation was prepared at one time to treat 250 acres at the rate of 2 pounds of DDT per acre. All the preparations contained approximately 10 per cent (wt./vol.) of DDT. For the oil solution 71.5 pounds of technical DDT was dissolved in 27 gallons of a medium-boiling aromatic fraction and then added to No. 2 fuel oil. For the emulsion 71.5 pounds of DDT and 28.6 pounds of an aralkyl polyether alcohol[2] were dissolved in 27 gallons of the solvent[1] and mixed with water. The suspension was made by stirring 143 pounds of a 50-per cent DDT wettable powder into 50 to 60 gallons of water and then adding more water.

To measure the effect of the sprays on the adult fly population, fly traps baited with beef liver were used. Three traps were placed about 50 feet apart to form a triangle in the center of each treated plot. To observe the over-all reduction, three traps were placed in the center of the entire 750 acres. Six traps were operated about 4 miles from the area to be treated. Starting 2 days before the first spraying, records of the number of flies caught were made daily. Flies were taken from the traps at 8 o'clock in the morning and then measured by volume. A small portion was identified as to genus and species. Other methods of sampling included exposing pieces of liver or liver extract in pint jars near the center of each plot. The liver extracts were exposed for 5 minutes in the morning during which time the flies attracted to the media were counted. The solid-liver baits (4 oz. per jar) were exposed continuously, and fly counts were made in mid-morning.

Table 1.—Reduction of flies as indicated by fly traps after airplane spraying of pasture at Menard, Tex., with DDT at the rate of 2 pounds per acre. April 1945.

Treatment	Date Sprayed	Percent Reduction[1] in Treated Plots on Indicated Days After Treatment						
		1	2	3	4	10	12	16
Emulsion	April 25	58	7	6	0	10	—	—
Solution	April 24	32	68	46	13	3	38	—
Wettable powder	April 23	46	17	56	26	15	15	11
Center of total sprayed area		71	60	76	66	61	26	38

[1] The percentage based on volume of flies (in cc.) caught in treated and untreated plots before and after applying the sprays, and calculated according to a modified Abbott's formula, as follows: $\frac{\text{Per cent reduction in treated area—Per cent reduction in check area}}{\text{100—Per cent reduction in check}}$.

RESULTS.—The reduction of flies (Table 1) as indicated by fly-trap catches varied considerably in the different plots, ranging from 6 to 68 per cent during the first 3 days after spraying. The plot treated with the oil solution showed the greatest reduction. The best degree of control (60 to 76 per cent) was shown in the traps located in the center of the entire sprayed area. This was probably to be expected since these traps were located farthest from the edges of the area.

Although the data are not presented in this report, the reduction of flies, as determined by exposing solid-liver bait and liver extract to flies, showed somewhat better control than was demonstrated by traps. On April 27, 2 days after treatments were completed, the fly counts in the jars containing liver extract were from 60 to 69 per cent lower in the treated plots than outside the treated area and in the jars containing solid liver 36 to 72 per cent lower.

There was a reduction of flies in the

[1] *Solvesso No. 3.*
[2] *Triton X-100.*

treated area, especially near the center. Flies rest on vegetation and other sheltered areas at night, and because of this habit they may be in contact with residual deposits of an insecticide for a prolonged period. From the few observations made, control appeared to be much better in the morning than late in the afternoon. It is believed that several hours must elapse before infiltration of flies from outside the treated area increases the general population level.

Samples of several daily catches of flies from each trap were identified as to species. The variation of numbers of each species from day to day, both before and after treatment, was slight. *Phormia regina* (Meig.), the predominating species, accounted for approximately 55 per cent of all flies caught, *Callitroga macellaria* (F.) for about 37 per cent, and *Phaenicia* spp. for 5 per cent.

RECOVERY OF DDT ON GLASS SLIDES AND VEGETATION.—Glass plates 4½ inches square were used to sample the deposit in each plot. These plates were set out in a line perpendicular to the flight of the plane, and across the center of the plot. They were placed in pairs at 20-foot intervals over a distance of 300 feet. The deposit was washed from each pair of plates with acetone and made up to a known volume. An aliquot was taken for analysis, by the colorimetric method described by Schechter *et al.* (1945).

The recovery of DDT ranged from 55 to 100 per cent of the dosage released from the airplane. The average recovery was 2.01 pound per acre, or 100 per cent, on the plot sprayed with the emulsion; 1.59 pound per acre, or 78 per cent, on the plot sprayed with the solution; and 1.11 pound per acre, or 55 per cent, on the plot sprayed with the water suspension. The recovery for individual plates ranged from 0.21 to 4 pounds per acre. These figures cannot be used as absolute figures for the deposit of DDT obtained on each plot, because the collections were taken over a line only 300 feet in length. Variation in wind drift or pilot error in flying swaths could easily cause deviation from the expected recovery.

Foliage from the treated mesquite and live oak trees was also tested. Leaves were picked at random from growth around the fly trap nearest to the center in each area. They were collected immediately after the spraying and each week for 4 weeks. All the leaves were thoroughly dried before they were analyzed for DDT residue. The check leaves for the first collection were obtained from all three areas before the sprays were applied; those for the later collections were taken from an untreated area. Analyses of data secured by determining the amount of DDT residues on leaves indicate a reduction of up to 91 per cent in the DDT residue after 2 weeks of weathering.

SUMMARY AND CONCLUSIONS.—Airplane spray tests with DDT were conducted against blow flies near Menard, Texas, in 1945. The DDT was applied at the rate of 2 pounds per acre as an emulsion, a suspension, and an oil solution, on three adjoining 250-acre plots within a large range area sparsely covered with low, small-leafed brush and trees. Applications were made from a PT-17 airplane.

DDT deposits collected on glass plates and determined by chemical analysis ranged from 55 to 100 per cent of the total dosage released from the plane. Analysis of leaf samples indicated a marked reduction of DDT 2 weeks after spraying mesquite leaves and live-oak leaves in two plots.

The best control of blow flies (60 to 76 per cent) was obtained in the center of the entire 750-acre sprayed area. The effectiveness of the treatments, as evaluated by liver-baited fly traps in each 250-acre plot, varied considerably. The range during the first 3 days after treatment was from 6 to 68 per cent.

It is concluded that to obtain maximum control of blow flies extensive areas must be sprayed with DDT. Treatment of small plots with relatively high single dosages of DDT will not give satisfactory control of flies. These results in general support those obtained by the Naval Medical Research Unit No. 2 previously mentioned.

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Relation of Droplet Size to Toxicity in Residual-Type DDT-Oil Sprays

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When insecticides are applied from airplanes, much of the material may be lost by drifting. This loss may be reduced by increasing the size of the particles so that they will be less affected by wind and air currents. An increase in droplet size, however, may change the effectiveness of the insecticide. Therefore, laboratory tests were conducted to determine the relation of droplet size to toxicity in residual-type DDT-oil sprays.

MATERIAL AND METHODS.—Technical DDT was used in these tests. In the early tests it was dissolved in xylene and fuel oil No. 2 and in the later tests in an alkylated naphthalene fraction.[2]

Droplets of uniform size were made by momentarily touching the tip of a fine-pointed pipette to the inner bottom surfaces of petri dishes. This inside surface of each dish had previously been rendered oleophobic by the following method: After being thoroughly washed and dried, the dishes were rinsed with about 30 ml. of acetone; after they had dried, a thin coating of a mixture of methylchlorosilanes[3] was applied to the inside bottom surface, which was then polished with a cloth. Droplets of different sizes were made by using pipettes with tip openings of various sizes. The petri dishes were 90 mm. in diameter and about 16 mm. high.

Since each droplet formed a planoconvex lens on the glass surface, it was possible to calculate the lens volume from the refractive index of the solution (n) and the diameter (d) and focal length (f) of the lens. The focal length was determined by focusing a microscope through the droplet lens on the image of some distant object, such as a window frame; using the parallel light rays reflected by the plane surface of the mirror, without the condenser, to get an undistorted image; and measuring the distance from this focus point to the glass surface with the calibrated fine-focusing adjustment on the microscope. The radius of curvature of the spherical surface of the lens (r) equals $f(n-1)$, the height of the lens $h = r - \sqrt{r - \frac{d}{2}}2$ and the volume of each lens equals $\frac{1}{3}\pi h^2(3r-h)$. The diameter of a spherical droplet with volume equal to that of the lens is then readily calculated.

All droplets with spherical diameters larger than 200 microns were measured, whereas only 5 to 15 of the smaller droplets were measured from each dish. All measurements were made within about 15 seconds after each droplet has been formed.

The test insects were 2-day-old adults of the wild type of pomace fly, *Drosophila melanogaster* Meig. They were reared at room temperature (24° to 26° C.) on a medium consisting of agar 15 gm., corn meal 110 gm., corn syrup 125 ml., dried yeast 15 gm., and 1 gm. of a mold-inhibiting substance[4] in 5 ml. of 95-per cent alcohol and 750 ml. of water. The flies that emerged during a 24-hour period were supplied with food and were not used until the following day.

The male flies were more easily killed than the females. In four replicated tests with each sex 3.2 micrograms of DDT caused 50 per cent mortality in the males in 24 hours, whereas 5.4 micrograms was required to give the same results with females. Because of this difference in the susceptibility of the sexes and because of the extra work involved in sorting, equal numbers of each sex were used per test.

The flies were anaesthetized with ether, and 30 of them were placed in each Petri dish on the untreated inside cover, together with a 1-ml. vial of food (6-per cent glucose solution seeded with yeast) stoppered with a cotton plug. After the flies had revived completely, each dish was carefully turned so that the treated surface became the floor. Room temperatures were kept between 24° and 26° C., and a 60-watt light located 3 feet from the dishes burned continuously.

The droplets were applied to the oleo-

[1] Acknowledgment is made of aid from F. C. Craighead, under whose direction the writer worked, and of advice regarding the analysis from F. M. Wadley.

[2] *Aro-Sol (151-B).*

[3] *Dri-Film.*

[4] *Moldex.*

Table 1.—Relation of droplet size to quantity of DDT causing 50 and 90 per cent mortality of pomace flies in 48 hours.

Spherical Droplets Diameter	DDT Causing 50 Per Cent Mortality	DDT Causing 90 Per Cent Mortality	Amount of DDT per Droplet	Tests
Microns	*Micrograms*	*Micrograms*	*Micrograms*	*Number*
DDT in xylene and fuel oil (0.1357 gm. per milliliter)				
79	1.8±0.1	4.1±0.3	0.035	9
197	1.9± .1	4.5± .5	.543	9
347	3.8± .2	6.2± .3	2.969	9
DDT in an alkylated naphthalene[1] (0.0916 gm. per milliliter)				
160	2.3±0.1	4.9±0.2	0.196	27
277	2.9± .1	6.3± .3	1.019	22
494	5.2± .4	12.3± .7	5.782	17

[1] *Aro-Sol.*

phobic surface during the morning, and the flies introduced in the afternoon.

Various dosages were tested for each droplet size, and the data obtained were analyzed by the probit method developed by Bliss (1935) for calculating the dosage-mortality curve. Adjustment for the mortality in the untreated checks was made with Abbott's formula. The average 48-hour mortality for the checks was 7 per cent.

RESULTS.—The results presented in table 1 show that toxicity was related to droplet size, smaller droplets being more effective than larger. In the tests with the larger droplets visible quantities of solution adhered to the dead flies—an indication that these individuals may have absorbed more DDT than was needed to kill them—thereby being unavailable to flies still alive.

Conversion of dosages to logarithms for the analysis resulted in asymmetric standard errors. Inasmuch as the difference was only a few hundredths of a microgram in most cases, only the mean standard errors are shown.

An inverse relationship between droplet size and surface area of the exposed droplet lenses was noted in the tests with DDT in the alkylated naphthalene. The mean surface area for 50 per cent mortality in 48 hours was 1.15 sq. mm. for droplets of 160 microns, 0.99 for 277 microns, and 0.89 for 494 microns. The preliminary tests with DDT in xylene-fuel oil, on the other hand, did not yield similar results. Although the writer places more significance in the results obtained with first named solvent[1] the difference could be due to the solvents; therefore, further work is necessary to elucidate this relationship.

Although the study was not conducted for the purpose of determining the mortality over an extended period of time, a few data up to 96 hours were collected (Table 2).

The results of tests with similar-size droplets of three concentrations of DDT in the alkylated naphthalene[1] are shown in table 3. The most concentrated solution was least effective, and the solution of intermediate strength appeared to be the best. For the 50-per cent mortality, however, the difference in dosage between the two lower concentrations was not significant.

Table 2.—Relation between droplet size and toxicity to pomace flies in approximately equal dosages of DDT over an extended time.

Droplet Diameter Microns	Per Cent Mortality After—				Micrograms of DDT	Tests
	24 Hours	48 Hours	72 Hours	96 Hours		
79	93	100	100	100	6.30	2
178	87	93	93	93	6.18	2
283	50	74	74	—	6.42	4
511	23	52	53	65	6.39	3

For seven tests with this solvent[1] used alone in quantities equivalent to those used for the DDT tests, the average 48-hour mortality was 5 per cent. Droplet size was 165 microns.

Table 3.—Relation of DDT concentration to dosage needed for 50 and 90 per cent kills of pomace flies in 48 hours.

DDT Concentration	DDT Causing 90 Per Cent Mortality	DDT Causing 90 Per Cent Mortality	Spherical Droplet Diameter	Tests
Gm. per ml.	*Micrograms*	*Micrograms*	*Microns*	*Number*
0.0916	2.9±0.1	6.3±0.3	277	22
.1832	2.8± .2	5.3± .3	285	12
.3664	6.3± .3	12.5± .8	252	15

SUMMARY.—Laboratory tests were con-

[1] *Aro-Sol.*

ducted to determine the relation of droplet size to toxicity in residual-type DDT-oil sprays. Uniform-size droplets of DDT solution were made by momentarily touching the tip of a fine-pointed pipette to the inner bottom surface of petri-dish test chambers. Droplets of different sizes were made by varying the size of the pipette openings. Tests against the pomace fly, *Drosophila melanogaster* Meig., showed that toxicity varied inversely with droplet size. Better dispersion of the DDT, obtained by using more dilute solutions and consequently a larger number of droplets, also increased the effectiveness of a given amount of DDT.

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The Control of Red-banded Leaf Roller with Parathion[1]

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During the past two years the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.) has become a major pest in Michigan apple orchards. In the summer of 1947, observations on its control were afforded by an orchard experiment in which parathion[2] was compared with DDT and lead arsenate. The latter material has been considered a standard remedy for red-banded leaf roller since the early work of Frost (1925) and Hough (1927). Informal reports from various states, as well as observations in Michigan, have indicated that DDT does not control this insect. In the 1947 growing season no information on the effect of parathion on red-banded leaf roller was available. However, a recent paper by Harman (1948) indicates that it has given satisfactory control in New York.

The work described in this paper was carried out in the Palmer Orchards at Leslie, Michigan. The orchard layout consisted of three separate blocks of trees, one each of Cortlands, Snows and Jonathans. Within each of the three large blocks a randomized block layout using seven treatments on single tree plots was set up. In the Cortland variety there were eight replicates in the Snow variety seven, and in the Jonathan variety six, making a total of 21 replicates for each of the seven treatments.

Standard, uniform spray treatments of wettable sulfur and lead arsenate were applied by the owner of the orchard through the first cover spray. Beginning with the second cover spray. on June 27, the following experimental treatments were applied:

A—4 lbs. of 15 per cent parathion[3]
B—1.75 lbs. of 15 per cent parathion
C—2.5 lbs. of 25 per cent parathion
D—1 lb. of 25 per cent parathion
E—3 lbs. lead arsenate, 1 lb. zinc sulfate and 4 lbs. lime
F—1.5 lbs. of 50 per cent DDT[3]
G—Check—no insecticide.

Following a 2-week schedule, four applications were made. In the first 2 applications 6 lbs. of wettable sulfur were added to each treatment, including the check. No fungicide was used in the last 2 applications. Maximum temperatures on the dates of application ranged from 73° to 95° F. The highest temperature at which parathion was used was 86° F. All treatments were applied with orchard sprayers (300-gallon tank, 35-gallon pump 500 pounds pressure, single gun, 0.11 inch dics) and all spraying was done from the ground.

At harvest time the yield of each tree was recorded and 2 bushels of fruit from each tree were scored for injury by red-banded leaf roller and injury by codling moth. In a few cases, where the total yield of the tree was less than 2 bushels, the entire yield was scored. The codling moth control data are being held for future publication. The data concerning

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[2] This work was supported in part by a grant from the American Cyanamid Company. In addition, the parathion used (*Thiophos 3422*) was supplied by the company.

[3] Wettable powder formulations.

yield and leaf roller control are tabulated shown in table 1.

Analysis of variance indicated no significant differences in yield due to treatment although there were significant differences between replicates in various parts of the orchard. Analysis of the leaf roller injury data indicated no significant differences among the replicates but showed highly significant differences among the treatments. At odds of 99 to 1, the significant difference between treatment means was 0.8 per cent.

Table 1.—Injury by red-banded leaf roller and yield of apples following treatments with parathion, lead arsenate and DDT. Each figure represents the average of 21 single tree plots.

TREATMENT	PER CENT LEAF ROLLER INJURY	YIELD IN BUSHELS PER TREE
4 lbs. 15% parathion	0.2	6.5
2.5 lbs. 25% parathion	0.2	7.5
3 lbs. lead arsenate	0.3	8.7
1.75 lbs. 15% parathion	0.5	8.7
1 lb. 25% parathion	0.5	7.8
1.5 lbs. DDT 50%	2.5	8.7
Check	3.3	8.9

Four sets of leaf and apple samples for residue analysis were taken from the Jonathan trees during the season. The first was taken immediately before the last cover spray, the second as soon as the last cover spray had dried, the third 3 weeks later and the fourth at harvest time, 8 weeks after the last cover spray. The results of the analysis are tabulated in table 2.[1]

The best control of red-banded leaf roller was obtained by the use of 0.6 lb. of actual parathion per 100 gallons of water. However, it was not significantly better than the control obtained by 0.25 lb. of parathion or that obtained by 3 lbs. of lead arsenate. DDT gave poor control, significantly better than the check treatment, but not commercially satisfactory.

[1] Residue analyses were made by Dr. P. R. Averell of the American Cyanamid Co.

Table 2.—Parathion residues on apple fruits following spray treatments.

TREATMENT	RESIDUAL PARATHION (ppm)		
	Before Last Cover	After Last Cover	3 Weeks Later
4 lbs. 15% parathion	0.3	3.1	0.15
2.5 lbs. 25% parathion	0.6	3.4	0.19
1.75 lbs. 15% parathion	0.1	1.2	0.12
1 lb. 25% parathion	0.4	1.3	0.07

Equivalent dosages of the 15 per cent and 25 per cent formulations of parathion wettable powder mixed equally well in the tank, sprayed out equally well and gave practically identical results. No advantage of one formulation over the other was observed.

The yield records were nearly uniform, indicating little or no effect of treatment on yield. Since there were no insect infestations of a nature that would affect the yield, it would be expected to be uniform unless the spray applications had stimulated or retarded the development of the crop. No such effects were observed and no spray injury was observed during the season.

The chemical analyses indicate that within 3 weeks after spraying with parathion the residue on the fruit had decreased to less than 0.2 parts per million.

SUMMARY.—In replicated orchard treatments parathion used at the rate of 0.6 lb. per 100 gallons of water gave excellent control of red-banded leaf roller on Cortland, Snow and Jonathan apples, but not significantly better than 3 lbs. of lead arsenate or 0.25 lb. of parathion. DDT at the rate of 0.75 lb., gave inferior control. Wettable powder formulations containing 15 and 25 per cent parathion gave similar results when used at equivalent concentrations. Spray applications caused no significant change in yield and no spray injury was observed. Chemical analyses indicated negligible residues of parathion 3 weeks after spraying.

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SCIENTIFIC NOTES

Tests with DDT Against Active Nymphs of Oyster Shell Scale

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During the past few years the oyster shell scale *Lepidosaphes ulmi* (L.) has been building up to damaging proportions in some Wisconsin apple orchards. In extreme cases trees are killed from scale injury.

Dormant oil sprays in 1946 and 1947 did not give satisfactory control. The control obtained was determined by collecting new-growth twigs from different parts of the treated and untreated orchards and examining under the binocular microscope; noting the live, dead, and parasitized scales present. A total of 300 individual scales was examined from each orchard for each count, and specimens were taken from all the material gathered.

In 1946 the counts taken prior to hatching from orchards receiving dormant oil treatments showed average percentages of 60.1 per cent live scales, 31.5 per cent dead, and 8.4 per cent parasitized. Similar counts from neighboring orchards receiving no dormant treatments showed 45.4 per cent live scales, 34.9 per cent dead, and 19.7 per cent parasitized. A similar trend was observed in 1947. Average counts taken before hatching from orchards receiving a dormant oil application were 85.8 per cent alive, 8.9 per cent dead, and 5.3 per cent parasitized, as compared with an average of 64.6 per cent alive, 14.6 per cent dead, and 20.8 per cent parasitized from the unsprayed orchards.

The average percentage of scales containing live eggs from the untreated orchards in 1947 was 64.6 per cent, as compared with 67.8 per cent from orchards receiving a dormant spray for the year 1947 only, and 91.8 per cent from orchards receiving dormant applications in both 1946 and 1947.

The data presented above indicate (1) that the application of dormant oils did not satisfactorily control oyster shell scale in northeastern Wisconsin in 1946 and 1947, and (2) that dormant oil treatments substantially reduced the percentage of parasitism.

It will be noted that the percentage of live scales in orchards receiving only one application of dormant oil was much lower than that found in orchards receiving dormant applications in two successive seasons. Apparently this difference was due to the higher percentage of scales parasitized. These data suggest that the continued use of dormant oils for scale control will reduce the percentage of parasitism and hence give a higher percentage of live scales.

Since the dormant sprays failed to give control, several post-dormant spray treatments were tested. These experiments included a series of materials applied after bloom when the scale eggs had hatched and the young were in the "crawler" stage. A block of trees including Wealthy, McIntosh, and Snow varieties was used in this experiment. Each material was used in a one-treatment program, applied on June 14 and 15, 1946. With the exception of Summer oil, 50 per cent DDD and nicotine, each material was used on two 23-tree rows. These three materials were used on single rows because of space limitations in the experimental orchard.

All applications were made from the ground with the operator on foot. A tractor-drawn Friend sprayer with a power take-off and about 550 pounds operating pressure was used. Care was taken to cover the trees from the ground level up and each tree was sprayed from both sides. Approximately thirteen gallons of spray material were used per tree.

During the period from July 28 through August 12 counts were taken on these plots to determine the control obtained. These counts were made by selecting from each row 10 twigs from the Wealthy variety, and five each from the McIntosh and Snow varieties for examination. Only the 1946 growth was used in making these counts. Twigs were cut at the point of junction with the older wood and were taken from various positions on the trees. Data were obtained by counting and recording all the scales present on the first six inches of growth, beginning at the base or proximal end of the specimens. In general, practically all of the scales present were on the first 6 inches of growth.

Since the single-row treatments gave only half as many twigs for sampling purposes as the double row treatments, a second sample of twigs was gathered

Table 1.—Control of oyster shell scale with post-blossom sprays. Door County 1946.

MATERIALS[1] (APPLIED JUNE 14–15)	RATE OF APPLICATION	SCALES ON 40 TWIGS
50% DDT	2/100	7
Summer Oil[2] Nicotine Sulphate 40% (No fungicide)	1% 1–800	39
DDT[3]	6/100	174
A DDT mixture[4]	1–800	194
50% Dichlorodiphenyl dichloroethane	2/100	235
Nicotine-Oil[5] (No fungicide)	1/2%	292
Lime sulfur Arsenate of lead	1–60 3/100	1416
50% Methoxychlor[6]	2/100	2095
Lime sulfur Arsenate of lead	1–40 3/100	2341
Lime sulfur Nicotine Sulfate 40%	1–60 1–400	2425
Benzene hexachloride 50%	2/100	2572

[1] The fungicide used with all materials was Dow "Mike" Sulfur at 5/100, plus hydrated lime at 3/100.

[2] Superla type—Unsulfonated residue 94.2%, Oil 97.7%, Specific gravity .8571, Saybolt viscosity 80–90@100 F.

[3] 16.6% DDT and 20% 2,4,4',7-Pentamenthyl 1-2'-Flavanol

[4] 15% DDT, 28% tri-methyl naphthalenes, 12% other hydrocarbons, 45% water soluble tobacco compounds and other inert ingredients.

[5] Soluble Nicotine 5.7%, Unsulfonated residue 92.2%, maximum oil 91.3%, specific gravity .8665.

[6] dimethoxy-diphenyl-trichloroethane.

[1] Approved for publication by the Director of the Wisconsin Agricultural Experiment Station.

from these plots and averaged in with the original sample. The results of these counts are given in table 1. They show that the use of 50 per cent DDT wettable powder gave very satisfactory control.

Some burning from the summer oil (treatment 2 above) was evident though it was used at 1 per cent strength instead of 2 per cent as recommended. The use of summer oils is not feasible in Wisconsin due to the continued application of pre-blossom fungicide, generally liquid lime-sulfur, followed by post-blossom fungicide applications of either liquid lime-sulfur or one of the wettable sulfurs.

Since DDT gave the most promising results of the eleven insecticides and combinations tested in 1946, the 1947 experiments were centered on this material.

Two orchards in different counties each received two sprays of 50 per cent DDT at the rate of 2 lbs. of the wettable powder per 100 gallons of water for the control of the oyster shell scale after the eggs had hatched and the young were beginning to crawl. Two sprays were used in 1947 because of the prolonged hatching period.

Counts in these orchards were made in August to determine the effectiveness of the DDT applications. These counts were made by selecting at random 300 1947-growth twigs from each orchard. The number of scales present per twig was not determined, but if one or more scales were present the twig was listed as infested. (Table 2.)

Table 2.—Control of oyster shell scale on apple trees with DDT in northeastern Wisconsin—1947.

Orchard and Treatment	Per Cent of Twigs Infested	Per Cent of Twigs Clean
Orchard A—Door County 50% DDT—2/100 (2 applications)	9	91
Orchard B—Kewaunee County 50% DDT—2/100 (2 applications)	9	91
Orchard C—Brown County Arsenate of lead—3/100 (full season)	72	28
Orchard D—Door County Arsenate of lead—3/100 (full season)	79	21

The control of oyster shell scale in 1947 using DDT was again very good. Even though 9 per cent of the twigs were infested in DDT-sprayed orchards, observations showed that the infestation per twig was much lighter than in orchards not sprayed with DDT.

SUMMARY AND CONCLUSIONS.—The use of a dormant oil for oyster shell scale control in Wisconsin is not satisfactory, on the basis of two years' work with commercial and experimental treatments. The percentage of live scales was higher on trees receiving dormant oil treatments than on untreated trees. These tests indicate that the use of a dormant oil greatly reduces parasitism of the oyster shell scale.

Two years' results show that complete coverage with a DDT spray applied at the rate of 2 lbs. of 50 per cent wettable powder per 100 gallons of water will control oyster shell scale in Wisconsin if applied during the "crawler" stage. Only one application was used in 1946 but two were applied in 1947 due to the prolonged hatching period of the eggs.

Microtheca ochroloma, an Introduced Pest of Crucifers, Found in Alabama

F. S. CHAMBERLIN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*, and H. H. TIPPINS, *Alabama Department of Agriculture and Industries*

Small beetles collected by the writers on young cabbage plants at Springhill, Alabama, on March 20, 1947, were identified by H. S. Barber as *Microtheca ochroloma* Stål. These beetles are approximately 0.2 of an inch long and half as wide, with a black head and brown wing covers. They have a conspicuous pale-yellow or white border surrounding the wing covers, on each of which are four rows of deep pits or punctures. In size, color, and sculpture they differ from any known species native in the United States.

Microtheca ochroloma is reported to be a serious pest of crucifers in Argentina and Uruguay.[1] In 1945 a specimen was intercepted at New Orleans, on grapes from Argentina, by inspectors of the Bureau of Entomology and Plant Quarantine.

In a survey by the writers early in April 1947 the newly discovered chrysomelid was found to be well distributed within the city limits of Mobile, Alabama, and in a considerable surrounding territory in Mobile County. Specimens were collected at Springhill (4 miles west of Mobile), Theodore (9 miles southwest of Mobile), and about 1 mile north of the city limits of Mobile. These findings established that the insect was present within a total area extending approximately 12 miles north and south and 6 miles east and west. Limited observations by the writers, during the survey, failed to disclose the presence of *M. ochroloma* in Baldwin County, Alabama.

This beetle was found feeding on cabbage, collards, mustard, turnip, and radish. The infestations occurred principally on garden plantings of these crops and ranged from light to severe in intensity. Nearly all of the heavy infestations were confined to turnip, which appears to be the preferred food plant in this territory, although heavy infestations were observed occasionally on mustard and collards.

The first infestation discovered was in a small planting of newly set cabbage and consisted of approximately seven adults and a few small larvae per plant. A heavy dosage of a dust mixture containing 0.75 per cent of rotenone applied to this planting apparently killed all the adults and larvae present at that time. No other infestations of any consequence were observed on cabbage. It appeared that the beetles may have been compelled to feed on cabbage in this instance by the absence of more favored food plants. The beetles were abundant in small turnip plantings in the vicinity of Theodore, but were causing no apparent injury to the large plantings of commercial cabbage in that district. Young tender cabbage plants adjacent to heavily infested turnips in one field showed no evidences of feeding by this beetle.

When feeding on cabbage, turnip, or radish plants, the adults of *Microtheca ochroloma* make small, irregularly shaped holes in the leaves and feed upon the leaf margins. The character of the larval feeding on turnip and radish leaves is similar to that by the Colorado potato beetle on potato. No larval feeding was observed on cabbage, and no

[1] Unpublished records by H. L. Parker of the Bureau of Entomology and Plant Quarantine.

definite notes were made regarding the type of adult or larval feeding on collards or on mustard. The larvae fed frequently in groups, and when abundant they consumed large portions of the foliage of infested plants. *M. ochroloma* was not observed feeding on the stems or roots of plants.

Many of the adults observed during the first part of April were believed to have emerged recently from hibernation. Others had evidently been active for some time, since numerous larvae and a few pupae were taken in several instances. Adults confined in cages on April 9 deposited large numbers of eggs immediately after capture. Limited observations indicate that the species estivates during the hot summer months in the Mobile district.

Following the discovery of *Microtheca ochroloma*, the inspectors of the Bureau of Entomology and Plant Quarantine, under the direction of B. M. Gaddis, made a cooperative survey to ascertain whether the insect occurred in the Southern States and in New York and California. This survey, thus far, has revealed the following additional infestations in Alabama: On mustard in the vicinity of Citronelle in Mobile County approximately 25 miles northwest of Mobile; a light infestation on turnips in a garden plot in the Ellisville community about 2.5 miles west of Loxey in Baldwin County and 18 miles east of Mobile; and a single adult in a clump of sedge grass immediately east of Foley in Baldwin County, 35 miles southeast of Mobile. The surveys in other areas have yielded negative results through 1947.

Present Status of the Citrus Blackfly and Its Parasite *Eretmocerus serius* at Nassau, Bahamas

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In connection with other investigations at Nassau, Bahamas, observations were made January 22 to February 5, 1947, on the status of citrus blackfly, *Aleurocanthus woglumi* Ashby, and its aphelinid parasite, *Eretmocerus serius* Silv. Heavy infestations of the blackfly on citrus were reported in Nassau in 1931, when the Malayan parasite was introduced by P. A. Berry (Clausen and Berry 1932). Observations by C. P. Clausen in 1937[1] indicated that the blackfly was still abundant in places even though a heavy population of the parasite was present at the time.[2] Because of this situation, with its resulting risk of introduction of the pest in Florida, a further effort was made to effect more complete control by the biological method. A coccinellid beetle, *Catana clauseni* Chapin, previously introduced from Malaya into Cuba, was known from experience in the latter country to be capable of controlling heavy infestations. In May 1936 more than 1000 adults and larvae were collected by P. A. Berry in Cuba and released at Nassau in the hope that they would supplement *Eretmocerus* in controlling the infestations. Both beetles and larvae feed mainly on the egg and first-instar nymphs of the blackfly. Follow-up observations were not possible, so that it is not known whether or not the beetle became established.

[1] Unpublished report.

[2] Information obtained on Chipman grove indicated that introduction of the parasite had been delayed there because the owner doubted its effectiveness.

Present observations were made at five citrus groves and two home plantings. The procedure consisted in examining 250 to 1000 leaves per tree on from 4 to 100 per cent of trees present.

Blackfly infestations were found generally very scarce, there being only 99 infested leaves out of approximately 80,000 examined on 161 trees. Usually there was only one colony of 10 to 20 or more immature blackflies on each of these few leaves. No adults were observed. Of 1,983 immature blackflies counted, 32 per cent had been parasitized by *Eretmocerus serius*. Only one adult parasite was found.[3] Actual figures for parasitization mortality are doubtless higher than here reported, because some hosts had been killed by parasites that had not yet emerged or had died before emergence, as pointed out by Clausen & Berry (1932).

In the A. N. Chipman grove, which C. P. Clausen had found heavily infested in 1937, 7 of 40 trees examined had one or more infested leaves. Only 0.08 per cent of these leaves were infested with blackflies, averaging about 20 per leaf, and 25 per cent of them were parasitized. (The one adult *Eretmocerus* was found in the A. N. Chipman grove.)

It is concluded that the citrus blackfly is now well under control at Nassau. This apparently is due to the work of the parasite *Eretmocerus serius* possibly aided by *Catana clauseni*, though the establishment of that species has not been proved. However, the marked reduction in the infestations in 1947 as compared with those of 1937 indicates the presence of some controlling factor that was absent prior to the latter date.

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[3] Acknowledgment is made of identification by A. B. Gahan, the Bureau of Entomology & Plant Quarantine.

Change of Host Preference in *Colias philodice*

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The butterfly *Colias philodice* (the "clouded sulphur") is distributed over the United States and Canada east of a narrow Pacific coast belt. Throughout this area its larval food plant varies according habitat and availability. In agricultural areas it utilizes nearly all species of clover but prefers red clover to the others. In the northeastern United States it does not seem to be able to utilize alfalfa. This applies also to eastern California where complete development of the insect does not seem possible on that host. That is, development is retarded and sterility may result (Hovanitz 1943).

Other legumes have been noted as larval food plants but few of these have actually been studied. In the northern prairies (Alberta), *Vicia* has been noted as the only food plant utilized in large quantity. In Ontario and Quebec *Colias philodice* has been noted as attracted to species of *Vicia* and in Alaska and the Yukon territory to *Astragalus deflexus*.

For the most part alfalfa is ignored by *Colias philodice*. In areas having adjacent alfalfa and red clover fields in the Great Lakes states, adults of

C. philodice are proportionately more attracted to the red clover fields while the alfalfa butterfly (the "alfalfa catterpillar"), *C. eurytheme*, is more attracted to the alfalfa fields (Hovanitz 1948).

With this in mind, it was strange to note that *Colias philodice hageni* was the primary pest on alfalfa in the upper Arkansas River Valley of Colorado (August 1948). The adults were fully as common over the irrigated alfalfa fields in this area as I have ever seen *C. eurytheme* on California alfalfa. Leaves of the plants were well eaten and eggs and larvae were very abundant. There is little doubt that *C. philodice* in this area is able to utilize alfalfa as larval food, despite the fact that it does not do regularly either farther west, in Arizona and California, or farther east, in the lower parts of the Mississippi Valley and the eastern seaboard.

Both *Colias philodice* and *C. eurytheme* exist in the upper Arkansas Valley alfalfa fields. *C. eurytheme*, however, is relatively scarce. At Las Animas, Colorado, of 230 females of *Colias* counted in one alfalfa field only three were *C. eurytheme*. Westward from Las Animas to the foot of the Rockies, *C. philodice* was the primary *Colias* observed with alfalfa. Eastward, *C. eurytheme* gradually became commoner. Sixty miles to the east near the Kansas state line (Holly, Colorado) 47 of 118 male butterfiles counted were *C. eurytheme*. Still farther east, *C. philodice* had nearly disappeared. At O'Neill, Nebraska, of 51 female butterflies counted 48 were *C. eurytheme*.

This change of host specificity is of great economic interest for it illustrates that a given species of insect *may* change its host requirements for either geographical (thus climatological) or physiological reasons. The subspecific difference of the *Colias philodice* in Colorado from the *C. philodice* of the Mississippi Valley or the west coast is an indication of hereditary differences in visible characters. That these visible characters are antedated by physiological differences in growth should probably be recognized. These physiological differences may be related to the differences in host plant specificity.

Other factors must be taken into consideration. First, the climate of the *high plains* (upper Arkansas River Valley) is considerably different from the lower Mississippi Valley, being cooler and drier in the summer. Such a climatic difference *may* be sufficient to alter directly the dietary requirements of the insect, though this seems unlikely. Second, the strain of alfalfa used in the high plains is itself quite possibly different from that used in the Mississippi Valley or the eastern seaboard. *Medicago sativa* is divided into numerous physiological strains in the diverse geographical areas in which it is planted. Thus, a change in content of the plant rather than a change in the requirement of the insect may have occurred. But whatever may be the reason for the alteration of host, it seems evident that a physiological study of the relationship between the insect (particularly lepidopterous larvae) and its host requirements is a fundamental need, not only for the purely scientific value but also for the economic understanding of the host-parasite relationship.

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Chlorinated Hydrocarbon Insecticides for Control of the Horn Fly on Dairy Cattle in Texas

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The general use of DDT and the possible use of other residual insecticides, such as the methoxy analog of DDT, TDE, chlorinated camphene, and chlordan, for controlling the horn fly, *Siphona irritans* (L.), on dairy cattle has prompted many questions. Perhaps the foremost question is—which of the residual insecticides will give the greatest protection with the fewest treatments.

Personnel of the Kerrville, Tex., laboratory of the Bureau of Entomology and Plant Quarantine conducted field tests on dairy cattle throughout the 1947 horn fly season to obtain data that would help in answering this question.

The tests were begun between May 15 and June 1 and continued until October 6, when cool weather caused erratic fluctuations in horn fly populations. All the tests were conducted under similar conditions on small dairy herds in Kerr and Kendall Counties in Texas. All the animals were Jerseys of uniform grade. None of the herds had been treated previously for horn fly control during 1947.

Fly counts were made twice weekly, on Monday and Thursday, and when the population averaged 25 flies per animal, or as soon thereafter as practical, the herd was re-treated.

A spray containing 0.5 per cent of active ingredient was used to treat all the herds except one, which was treated with 0.25 per cent DDT. A 0.5 per cent concentration seemed to be the maximum at which the materials being tested would be practical for horn fly control. Two herds each were treated with each of the following materials: DDT, the methoxy analog of DDT, dichlorodiphenyltrichloroethane and chlorinated camphene. One herd was treated with 0.5 per cent chlordan and one herd with 0.25 per cent DDT. All the sprays were made from 50 per cent wettable powders, except the chlorinated camphene spray, which was made from 25 per cent wettable powder.

The insecticides were applied with a wheelbarrow-type power sprayer operating at a pressure of approximately 100 pounds per square inch. The spray boom had three nozzles arranged to give rapid coverage of the animal. Two nozzles approximately 6 inches apart produced a fan-shaped spray pattern, and a whorl-type nozzle was centered between them. The inside margins of the fan-shaped sprays intersected approximately 4 inches from the nozzles. With this arrangement the operator could spray an animal in about 30 seconds. Each animal was treated, while held in a stanchion, along the neck, back, sides, and the abdomen forward of the udder. Approximately 2 quarts of material was applied to each animal at each spraying.

The results of these tests, as shown in table 1, indicate that at a concentration of 0.5 per cent (1) all the materials tested gave satisfactory control, (2) chlorinated camphene and chlordan gave only slightly better protection than DDT, (3) the methoxy analog of DDT and dichlorodiphenyl dichloroethane were slightly inferior to DDT, and (4) DDT was much more effective than it was at a concentration of 0.25 per cent. However, horn flies were satisfactorily controlled with the 0.25 per cent DDT spray and, since the labor involved in the

Table 1.—Control of horn flies on dairy cattle with various residual insecticides. (Concentration 0.5 per cent unless otherwise indicated.)

Material	Number of Sprayings	Average Number of Animals Treated	Average Days' Protection
DDT 0.25%	5	25	17
0.5%	4	100	29
Methoxy analog of DDT	5	65	20
Dichlorodiphenyl dichloroethane	4	72	24
Chlorinated camphene	3	66	31
Chlordan	3	13	32

treatment of dairy cattle is usually less than for range animals, the lower concentration might be more economical and desirable.

Other observations in the field indicated that (1) of all the materials tested the methoxy analog of DDT gave the quickest and chlorinated camphene the slowest knock-down of horn flies, (2) in the Kerrville area during 1947 treatments spaced 30 days apart satisfactorily controlled horn flies when a 0.5 per cent spray was used, and four or five treatments were sufficient for the entire horn fly season, and (3) no animals were injured by any of the insecticides used, nor did the spray operator suffer any noticeable ill effects. However, this aspect did not include a thorough study of the toxicology of insecticides. Research on the toxic effects on livestock and storage or secretion of the chemicals in animal products will be presented in separate publications. The results presented in this paper therefore do not indicate that all these materials should be recommended for the control of this insect.

Duration of the Effect of Residual DDT Spray in Houses in Florida[1]

DOYLE J. TAYLOR,[2] J. A. MULRENNAN[3] and D. C. THURMAN[4]

Field inspections in unscreened houses[5] were made in Florida during 1947 to determine the residual effect of DDT house spray applications in controlling the malaria vector *Anopheles quadrimaculatus*. The houses included in the inspections were sprayed with DDT-xylene emulsion in one or more of the 1945, 1946, and 1947 mosquito seasons. Results of our 1947 inspections in Florida corroborate the finding of previous reports prepared from similar entomological inspection data in the southeastern states, published by Bradley & Fritz (1946, 1947). The effects of *quadrimaculatus* densities on the occurrence of *quadrimaculatus* infested houses as determined by inspections of natural resting stations and the time elapsed from spray application to the time of house inspection, have been studied by these authors. In addition to results similar to those of Bradley & Fritz; we have obtained information which indicates that applications of 5 per cent DDT-xylene emulsion applied at the rate of 200 mg. of DDT crystals per sq. ft. (the over-all average for the state was between 150 and 200 mg.) during the late months of one season will retain a high degree of effectiveness during the next season.

Two methods of measurement are used: (1) the percentage of *Anopheles quadrimaculatus*-positive houses and (2) the mean number of *A. quadrimaculatus* per house.

For the purpose of reporting the results of our observations on the effects of DDT house spraying, the houses inspected were divided among three groups (Table 1) as follows:

Table 1.—Results of DDT residual spray program for *Anopheles quadrimaculatus* in Florida 1945–1947.[1]

	Number Houses Inspected	Per Cent Houses with *A. quadrimaculatus*	Number *A. quadrimaculatus* per House
Houses Unsprayed	338	62.7	3.0
Houses Sprayed			
(A) In 1945 & 1946 or in 1946 only	303	7.6	0.3
(B) In 1946 & 1947 or 1945, 1946 & 1947	397	4.5	0.1
(C) In 1947 only	235	8.0	0.3

[1] Based on inspections made in 1947.

Group A. Those which had received treatments with DDT residual house spray in 1946 only, or in both 1946 and 1945.

Group B. Those which had received treatment with DDT residual house spray in 1947 less than 6 months before inspection and had also received treatment in either the 1946 season or both 1946 and 1945 seasons.

Group C. Those which received treatment with DDT residual house spray for the first time in 1947.

Data from group B inspections (Table 1) indicate that the 1947 sprays applied in houses sprayed previously reduced the mean number of *Anopheles quadrimaculatus* per house from 3.0 to 0.1, or more than 95 per cent when compared with conditions in unsprayed houses.

Inspections made during this study corroborate the findings of Bradley & Fritz that the increasing *Anopheles quadrimaculatus* density in natural resting stations produces a proportionate increase in the percentage of *A. quadrimaculatus*-positive houses in unsprayed areas, and a proportionate increase in the mean number of *A. quadrimaculatus* per house. In comparison with their report on 241 unsprayed houses inspected in areas of *A. quadrimaculatus* density above ten, producing 45.2 per cent vector-positive in 338 inspections (Table 1).

Based on data from the 632 inspections made in houses sprayed in 1947, groups B and C, a graph has been prepared to show the effectiveness of the 1947 spray application. The 94 per cent difference shown between the mean of three *Anopheles quadrimaculatus* per house in unsprayed areas, and the mean of 0.18. *A. quadrimaculatus* per house in sprayed areas may be attributed to the applications of the residual DDT sprays.

DURATION OF EFFECTIVENESS OF RESIDUAL OF 1946 SPRAYS.—The data presented in table 1 indicate that in controlling *Anopheles quadrimaculatus* the residual effectiveness of DDT house sprays ap-

[1] A contribution of the Communicable Disease Center Activities, U. S. Public Health Service and The Florida State Board of Health, Jacksonville, Florida.

[2] Entomologist, U. S. Public Health Service.

[3] Chief, Division of Entomology, Florida State Board of Health.

[4] S. A. Sanitarian (R), U. S. Public Health Service.

[5] Acknowledgement is made of the assistance of Entomological Inspector, Carlis J. McLeod in making field observations.

plied during the 1846 season lasted for 6 to 12 months from the time of the initial applications, and extended into the 1947 season. Approximately 90 per cent of this effectiveness was retained more than six months as measured in numbers of *A. quadrimaculatus* in sprayed houses, as compared with similar data for unsprayed houses. Of houses which had received residual spray in the 1946 season, only 7.6 per cent contained live *A. quadrimaculatus* when inspected. Comparing these results with the data on unsprayed houses which showed that 62.7 per cent of unsprayed houses are normally infested with *A. quadrimaculatus*, the 1946 applications appear to be 88.1 per cent as effective during the 1947 season as in 1946.

SUMMARY AND CONCLUSIONS.—Results of house inspections and inspections of adjacent natural resting places for *Anopheles quadrimaculatus* during the 1947 mosquito season are analyzed to determine:

(1) The effect of the 1947 residual DDT house spray upon the populations of *A. quadrimaculatus* in such houses during the 1947 season.

(2) The duration of effectiveness of the 1946 residual DDT house spray applications.

The percentage of *Anopheles quadrimaculatus*-positive unsprayed houses is higher in the areas of greater vector density, therefore corroborating previous findings.

Of 338 unsprayed, unscreened houses in Florida inspected in 1947, 62.7 per cent were found infested with *Anopheles quadrimaculatus*, the mean number of *A. quadrimaculatus* per house was determined as three.

The residual effectiveness of the 1946 DDT house spraying is shown to be 88.1 per cent as effective during the 1947 season as in 1946, such effectiveness lasting from 6 to 12 months from the time of initial application.

Results of inspections show that in areas of vector densities above 10 the 1947 DDT residual spray applications kept more than 90 per cent of houses free from *Anopheles quadrimaculatus* that normally would have been infested, and the number of *A. quadrimaculatus* that normally would have occurred in these houses was reduced by 94 per cent.

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A Leafhopper Injurious to Cultivated Prune in the Western United States

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On several occasions during the past 4 years specimens of *Typhlocyba* collected from culitivated prune in the western United Sates have been received for identification. Although occasionally specimens of the rose leafhopper, *T. rosae* (L. have been found in the samples, the material has been preponderantly *T. prunicola* Edwards. Since these submissions suggest that the species is becoming more widely distributed and more important as a pest, it seems worth while to summarize distribution records and literature references.

Typhlocyba prunicola is known to occur in Europe, having been recorded from England, France, and Sweden. It is assumed to be an introduction into the United States, since the earliest collection record for this country appears to be 1930, when DeLong & Haegele found it injuring cultivated prunes in Idaho (type material of *pruni* DeLong & Davidson). Haegele's note[1] presumably applies to this species, although he reported it under the name of *pomaria* McAtee. I have examined North American material from the following localities, all records being from "prune" or "plum": California, Berkeley, San Jose; Idaho, Boise, Parma; Oregon, Milton; Utah, Bountiful; Washington, Yakima.

The synonymy of the species and literature references known to me are as follows:

Typhlocyba prunicola Edwards, Ent. Monthly Mag. 50: 168, 1914.

Anomia prunicola Edwards, Ent. Monthly Mag. 64: 62, 1928.

Typhlocyba barbata Ribaut, Bul. Soc. Hist. Nat. Toulouse 61: 337–9, 1931.

Typhlocyba pruni DeLong and Davidson, Ohio Jour. Sci. 34: 161–2, 1934. (New synonymy.)

Typhlocyba barbata Ribaut; Wagner, Verhandl. Ver. naturw. Heimatforschung Hamburg 24: 32, 1935.

Typhlocyba barbata Ribaut, Faune de France 31, Homop. Auchon. I, Typhlocybidae, pp. 99–100, 1936.

Typhlocyba prunicola Edwards; Ossiannilsson, Opuscula Ent. 4: 26, 1939.

Typhlocyba prunicola Edwards; China, Trans. Soc. British Eng. 8: 114–5, 1943.

Typhlocyba pruniella DeLong (*pruni* DeLong and Davidson, 1934, not *pruni* Edwards, 1888), Ohio Jour. Sci. 44: 272, 1944. (New synonymy.)

Typhlocyba pruniella DeLong; DeLong and Knull, Ohio State Univ. Graduate School Studies, Biol. Sci. Ser. no. 1, p. 76, 1945.

Typhlocyba prunicola Edwards; Ossiannilsson, Svensk Insektfauna 7 Halvvingar, Hemiptera, p. 139, 1946.

For illustrations of the diagnostic characters of value in distinguishing *prunicola* from closely related species, workers are referred to the excellent figures in Ribaut, 1936.—9-28-48.

Chlordan Compared with Parathion on Plums

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For a number of years the writer has been interested in attempts to control the plum curculio on 20 old damson plum trees of the French type. The trees planted in two rows along the edge of an old orchard have long been neglected from the standpoint of pruning and other cultural care. A thick growth of sod and honeysuckle under many of the trees and along an adjoining fence row provide an excellent harbor for the overwintering beetles.

In 1948 five trees at the north end of the two rows where damage has always been least were left

[1] *Jour. Econ. Ent. 23: 884, 1930*

Table 1.—A comparison of the effects of chlordan and parathion when used on plum trees to control the plum curculio.

PLOT	INSECTICIDE (ACTUAL) IN 100 GALLONS OF WATER	FRUITS DAMAGED BY CURCULIO	REMARKS
		(*Per Cent*)	
A	Parathion 8 oz. in 4 sprays ending May 11.	2.5	No treatment injury.
B	Parathion 8 oz. in 5 sprays ending May 21.	0.8	No treatment injury.
C	Chlordan 0.8 lb. in one spray then 1 lb. in 3 sprays ending May 11.	2.9	Severe damage to foliage caused by spray treatment. Fruit grew to only half normal size.
D	Check, not sprayed.	57.3	Foliage as in A & B.

as checks and the remaining trees were sprayed as follows, the quantities of materials being for 100 gallons of water; plot A, 2 pounds of 25 per cent parathion wettable powder[1] in late bloom (April 16), petal-fall (April 23), shuck-fall (May 1), and first cover (May 11); plot B, parathion same as in A, excepting an additional application was made on May 21; plot C, 2.5 pounds of 40 per cent chlordan wettable powder[2] in same schedule of sprays as for plot A, excepting only that 2 pounds of the chlordan was used on April 16. Observations made during the week following the spray on April 16 indicated that this application probably could have been omitted without influencing results on control. From late June until harvest-time an elemental sulfur fungicide was applied at weekly intervals on all trees to control brown rot.

RESULTS.—Satisfactory control of the plum curculio was obtained as shown in the accompanying table. But the most outstanding feature of the test was the severe damage caused by the wettable chlordan treatment. Soon after the third application on May 1, the young leaves began to twist and curl as though scorched; further growth was inhibited. The application on May 11 intensified the injury, caused severe defoliation and killed terminal buds. No new leaves developed thereafter. The fruit did not drop, nor was there any evidence of spray injury on the surface, but at harvest time the plums were scarcely half their normal size.

Trees sprayed with parathion showed no evidence of spray injury and all bore a heavy crop of fruit. Parathion residue[3] on plums picked when the fruits were about half grown, on June 7, was as follows: plot A, 0.08 p.p.m.; plot B, 0.4 p.p.m.; check, not sprayed, 0.02 p.p.m. At harvest-time (July 22) parathion residue on the sprayed fruit had disappeared, residue analysis being the same as for the unsprayed fruit, namely 0.02 p.p.m.

According to this test, chlordan is highly toxic to plum foliage and buds when applied at the time the plum curculio is active in Virginia. On the other hand, parathion appeared to be a promising insecticide to control this insect on plums.

[1] *Thiophos* furnished by the American Cyanamid Co.
[2] *Chlormix*, furnished by the Sherwin Williams Co.
[3] Determined by Analytical Research Laboratory of the American Cyanamid Co.

Pediculoides ventricosus, a Predatory Mite Attacking the Bud Moth

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During the course of investigations on the bud moth, *Spilonota ocellana* (Denis & Schiffermüller), on prunes in Santa Clara Valley, California, it was noted that the larvae were being attacked by a predatory mite. Subsequent investigation showed the mite to be *Pediculoides ventricosus* (Newport), a species that primarily attacks stored products insects, but also attacks a large number of agricultural pests.

The biology of *Pediculoides ventricosus* has been studied extensively by Herfs (1926) and other workers. Tothill (1930) has studied its biology in relation to the coconut moth, *Levuana iridescens* Bethune-Baker, in Fiji. There have been numerous reports in the literature of its attack on many stored products and agricultural pests as well as humans, but usually it is of minor importance economically with respect to agricultural pests.

The mite was observed feeding on the bud moth larvae during the late fall and winter months when the latter was in a resting stage within a hibernaculum. It was not observed during the summer months at which time the larvae are active and feeding. Usually a larva is attacked by more than one mite, the maximum number observed in the field was 8, although larger numbers have been recorded in the literature with respect to other hosts. The mite seems to inject some poisonous substance into the larvae, as laboratory observations showed the larvae die soon after being attacked. A gravid female mite attached to the larva appears with the abdomen enormously swollen, spherical in shape, mottled yellow and brown in color, and protrudes from the transparent head and thorax. In this stage the female is incapable of movement and soon begins to produce young. In the laboratory it took from 5 to 6 days for the mite to attain its maximum size. Young are born alive and sexually mature, the males emerging first and remaining on the gravid females until the young females emerge, at which time mating takes place. In the field, the males, which are

very small and almost transparent, could be seen with difficulty on the gravid females.

Examination of the bud moth hibernaculae in the field disclosed dead larvae with living mites attached and others dry and shriveled with the mites no longer in evidence. Since observations disclosed no other predators or parasites attacking the larvae during the course of this investigation, it is probable that most of these shriveled larvae were killed by *Pediculoides*.

Field surveys over a period of 5 months showed considerable mortality among the larvae of the bud moth as a result of attack by *Pediculoides*. The percentage of natural mortality, most of which was due to the mite, increased monthly up to the last survey which was made on January 10, 1948. The results of the surveys are summarized in the following table:

Table 1.—Field survey of larval natural mortality.

Date of Surveys	Larvae Examined	Live Larvae	Dead Larvae		Per Cent Natural Mortality
			Mites Present	Mites not Present	
Oct. 28	107	60	20	27	33
Nov. 21	114	59	35	20	48
Dec. 9	112	49	36	27	52
Jan. 10	106	45	24	37	56

CONCLUSIONS.—Tue data obtained in the field indicates that *Pediculoides ventricosus* may be an important factor in the natural control of the bud moth in the Santa Clara Valley. However, further observations are necessary to determine whether this high percentage of attack is a usual seasonal occurrence.—1-17-48.

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The Establishment of the Chinese Race of *Comperiella bifasciata* on *Aonidiella aurantii* in Southern California

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The successful establishment of *Comperiella bifasciata* How. on the California red scale, *Aonidiella aurantii* (Mask.), in at least two localities in southern California brings to a conclusion a remarkable series of developments in connection with attempts to introduce and establish *Comperiella* on this scale. Smith (1942) points out that 35 years after the first introduction was made a race of *Comperiella* was finally obtained in 1941 which successfully parasitized the California red scale in the laboratory. He showed that the final success of this phase of the project depended upon the solution of several obscure entomological problems including the ability of taxonomists to separate *Aonidiella aurantii* from *A. taxus* and *A. citrina*, and the determination that the host plant can make an insect feeding upon it immune to parasitization by its normal parasites.

Immediately following the introduction by the University of California of the Chinese race of *Comperiella* in 1941, mass culture was undertaken and over 2 million female and male parasites were produced in the insectary during the next 15 months (Flanders 1943).

Intensive liberations of this insectary-produced material were made in the major red scale districts of Los Angeles, Orange, Riverside, San Bernardino, Santa Barbara, and San Diego counties as well as in Ventura County. Although first generation recoveries were fairly common, it appeared as time passed that permanent establishment was questionable. According to Flanders (1944), "Reproduction of this China race has . . . occurred to a limited extent in the field in California but establishment is yet uncertain, and there is no indication that it is able to control red scale." In fact, until 1946, establishment, Flanders informs me, was known only on a few dooryard trees on one property in Riverside. In 1946 California red scale was found by D. L. Lindgren of the Division of Entomology to be commonly parasitized by *Comperiella* on the grounds of the University of California Citrus Experiment Station.

Definite establishment of *Comperiella* on California red scale in a locality other than Riverside was ascertained for the first time in January, 1948, when *Comperiella* was found to be abundant in a heavily infested lemon grove at Escondido, Subsequent collections showed *Comperiella* to be generally distributed in the Escondido area. During 1948 red scale infestations have been checked in groves in San Diego, Santa Barbara, Orange, Los Angeles, San Bernardino, and Riverside counties, but *Comperiella* was not recovered except in the two previously mentioned localities.

It is possible that of the 2 million odd *Comperiella* released only a few were genetically constituted to survive under field conditions in southern California. Those established may, therefore, represent a strain superior to the original mixed stock in the ability to survive in southern California. Individuals from the Riverside "strain" are now being reared in the insectary and will later be released in the field in areas now without *Comperiella* in order to determine if, in fact, they are superior to the individuals liberated originally in 1941–42.

The actual effectiveness of *Comperiella* against California red scale does not appear to be great in the Riverside or Escondido areas. Generally speaking, *Comperiella* becomes abundant when scale is abundant. It may reduce peak infestations of red scale but evidence thus far indicates that it is not efficient in infestations of low density.—9-29-48.

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New Insecticides for Cotton Insect Control[1]

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Cotton insect control experiments at the North Carolina Experiment Station in 1947 were confined to small plot tests for the control of the boll weevil, *Anthonomous grandis* Say, and the bollworm, *Heliothis armigera* (Hbn.). In these tests, observations were made on red spider abundance but no control tests were planned for this pest.

PLOT DESCRIPTION.—The 1947 tests were conducted in a 4-acre field of *Coker* 100 wilt resistant cotton 5 miles east of Raleigh. This particular field had been planted to cotton for the past 5 years. The 1947 stand appeared in good condition in May. Examination of the field in June showed a moderate degree of boll weevil injury. It was apparent at this time that the soil fertilization had been inadequate. During the 1947 season, the field had received the following amounts of fertilizer: 625 pounds per acre of a standard 4-8-8 fertilizer in the drill at the time of planting plus 74 pounds per acre of nitrate of soda after the cotton had been chopped or thinned to a stand. The field was cultivated three times, the last cultivation being done in late June. The stand was not ideal for tests involving high yield but it did provide good conditions for the testing of the effectiveness of insecticidal controls.

Plots were ten rows wide and 75 feet long. No barrier zone separated the plots. The entire area of the plots was about 1.5 acres situated in the center of the 4-acre field. The field was bounded on two sides by field corn.

PROCEDURE.—Five treatments were used, including an untreated check. The treatments are listed in table 1.

In addition, a check strip was located in the center of the test area. The test was replicated four times in randomized blocks.

Cotton surrounding the treatment area was not dusted at any time during the season. The first application was made July 22, after a square examination on July 18 showed an average boll weevil egg-puncture count of nearly 17 per cent. A square count made on July 29, 1 week after the first dusting, showed that the moderately-high infestation of July 18 was down to less than 10 per cent. In order to permit a build-up of the weevil infestation, dusting was not resumed until August 6. A square-count made on August 5 showed a very marked increase in weevil egg punctures.

All dust applications were made at 5:00 to 7:00 a.m. Dew was moderately heavy at this time of day. Wind was usually negligible which assured a minimum of drift and good dust coverage. A total of 5 dust applications was made during the season. Dusts were used at the rate of 10 pounds per acre. Dust applications were made with a rotary type hand gun.

Square-counts were made on six different dates; the first count was made before the season's program of dusting was begun. The five other counts were made a day or two before dusting. The typical square count consisted of counting 10 squares on 10 different plants in each of the 10 rows, making a total of 100 squares per plot on each examination date.

The dates of the square counts as well as the dates of dusting are presented in table 1. No rain fell within 24 hours after any of the treatments.

Only one bollworm examination was made. This was on September 12, 2 weeks after the last regular dust application. The percentage of infestation was based on a count of 100 bolls in each plot, as described above.

Plot yields were based on the complete picking of the two center rows of each plot.

RESULTS.—Table 1 lists the data on square-counts and yields. The results of these tests were analyzed statistically. The only measurable response in yields was that all of the treatments were higher than the check. The plot to plot variation was so great that it was impossible to distinguish between the four insecticides.

There was no significant reduction in boll weevil infestation due to any of the insecticides. There was no consistent relationship between yields and infestation of weevils or of bollworms.

The highest yield was obtained in the plots treated with 20 per cent chlorinated camphene. The lowest bollworm infestation was recorded in this treatment. The lowest average boll weevil infestation (average of five counts) was recorded in the 5 per cent gamma benzene hexachloride treatment.

SUMMARY.—Field tests for cotton boll weevil and bollworm control were conducted in small replicated plots in a field near Raleigh, North Carolina. Dust treatments were made with (1) 20 per cent chlorinated camphene, (2) a combination dust of 3 per cent gamma benzene hexachloride and 5 per cent DDT dust, (3) 5 per cent gamma benzene hexachloride and (4) 5 per cent chlordan. Untreated checks consisted of (1) randomized check plots located in randomized blocks of the treatment area, (2) a cen-

[1] Presented at the Southeastern Cotton Insect Control Conference, Columbia, South Carolina, December 8, 1947.

Table 1.—1947 Field plot tests for control of the cotton boll weevil and bollworm, Garner, North Carolina.

Materials Used[1]	Per Cent Egg Punctures (Average of 4 Replicates)						Average Per Cent Infest.	Per Cent Bollworm Infest.	Seed Cotton Lbs./Acre
	7/18	7/29	8/5	8/9	8/14	8/18	7/29–8/18	9/12	
20% Chlorinated Camphene[2]	21.5	2.75	29.5	54.5	57.0	32.75	35.30	2.75	1,007
3% gamma Benzene hexachloride and 5% DDT	14.5	6.5	32.0	53.0	47.5	32.5	34.30	6.5	958
5% gamma Benzene hexachloride[3]	15.25	1.8	17.25	45.5	54.5	29.0	29.61	12.5	934
5% Chlordan[4]	18.5	6.25	34.5	64.0	65.0	41.5	42.25	11.5	855
Check—no treatment	19.0	5.75	29.5	56.5	67.25	54.75	42.75	12.5	728

[1] Treatment Dates: July 22, August 6, August 11, August 16, August 19, August 29.
[2] Chlorinated Camphene supplied by the Hercules Powder Company, Wilmington, Delaware.
[3] Benzene Hexachloride supplied by the California Spray-Chemical Corporation, Elizabeth, New Jersey.
[4] Chlordan furnished through the courtesy of the Velsicol Corporation, Chicago, Illinois.

ter strip of check plots dividing the treatment area into two pairs of randomized blocks.

Five dust applications were made from July 22 to August 29. Each application received 10 pounds of dust per acre, applied with a rotary type hand gun. Lowest average weevil infestation at the end of the season was recorded for the 5 per cent gamma benzene hexachloride treatment; lowest bollworm infestation, in the 20 per cent chlorinated camphene treatment. The highest yield, based on total picking of seed cotton in two center rows of plots 10 rows wide by 75 feet long, was recorded in the 20 per cent chlorinated camphene treatment.

The Willamette Mite, a Pest of Raspberries in the Puyallup Valley[1]

E. P. BREAKEY[2] and G. S. BATCHELOR[3]

The Willamette mite, *Tetranychus willamettei* McGregor, became a serious problem for the raspberry growers in the Puyallup Valley of western Washington in 1947. The unwise use of DDT in the campaign against the orange tortrix, *Argyrotaenia citrana* (Fernald), was doubtless a contributing factor. For example, a survey of growers disclosed that, without exception, where DDT had been used, a serious infestation of mites had developed, but where cryolite only had been used, mites were present but not in harmful numbers. The season ended with the largest mite populations on record.

Mites were first noted in appreciable numbers about the time the raspberries began blossoming. The mite population began to build up on the undersides of the lower leaves. As the season advanced, the population moved up the canes and by the middle of summer injury to the leaves was severe. This injury appeared as a drying or burning of the leaf, first around the margin, then later the entire leaf became affected. No webbing was observed at any time.

Tests were made during the summer of 1947 to determine the effectiveness of some of the better known acaricides, particularly when used in combination with some of the newer insecticides. The results of these tests are given in tables 1 and 2.

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Table 1.—Control of Willamette mite on raspberries, Alderton, Washington, 1947.

TREATMENT	TOTAL NO. LIVE MITES IN 50 MICROSCOPIC FIELDS	
	24 Hrs.	48 Hrs.
Dichlorodiphenyl dichloroethane—2 lbs. plus 8 oz. Dinitro compound[1] per 100 gallons	274	263
Cryolite—2 lbs. plus 8 oz. Dinitro compound[1] per 100 gallons	775	1091
DDT—2 lbs. plus 8 oz. Dinitro compound[1] per 100 gallons	1258	1644
Methoxychlor—2 lbs. plus 8 oz. Dinitro compound[1] per 100 gallons	3705	4544
Checks—No Treatment	9693	8135

[1] DN-111 (Dow) is a spray powder containing 20% dicyclophexylamine salt of dinitro-o-cyclohexylphenol.

Table 2.—Control of the Willamette mite on raspberries, Alderton, Washington, 1947.

TREATMENT	TOTAL NO. LIVE MITES IN 50 MICROSCOPIC FIELDS	
	24 Hrs.	48 Hrs.
Dichlorodiphenyl dichloroethane—2 lbs. plus 20 fl. oz Hexaethyl tetraphosphate formula[1] per 100 gals. spray	396	298
DDT—2 lbs. plus 20 fl. oz. Hexaethyl tetraphosphate formula per 100 gals. spray	647	546
Cryolite—2 lbs. plus 20 fl. oz. Hexaethyl tetraphosphate formula per 100 gals. spray	1315	1201
DMT—2 lbs. plus 20 fl. oz. Hexaethyl tetraphosphate formula per 100 gals. spray	1551	1484
Checks	5347	5302

[1] *Lethex* (Vis Ko, Inc.); Hexaethyl tetraphosphate 25% in a miscible base.

The sprays were applied with a power sprayer equipped with two upright booms each of which carried four nozzles that had been adjusted to provide the best coverage possible. The sprayer was drawn between the rows with a tractor. The materials used and the spray formulae are contained in the tables. These tables are largely self-explanatory.

The effectiveness of each treatment was determined by taking fifty leaves at random from a uniform height. The binocular microscope was focused on the lower surface of a leaf and all living mites appearing in the field were counted. This leaf was then discarded and another leaf examined. Counts were made at intervals of 24 and 48 hours following the application of the sprays.

It will be noted that the efficiency of a dinitro compound was greatly reduced when combined with DDT and dimethoxytrichloroethane as compared with dichlorodiphenyl dichloroethane and cryolite. Moreover, the dinitro compound gave good results when used with cryolite or dichlorodiphenyl dichloroethane. This was gratifying since it will probably be desirable to include an acaricide when spraying for the control of the orange tortrix and dichlorodiphenyl dichloroethane is the most promising of the newer insecticides that have been used against that insect. A formula containing 25 per cent hexaethyl tetraphosphate[4] also showed promise, particularly as a means of quickly reducing the adult populations. Just why the acaricides failed to show better control when used with the other insecticides is a mystery. Apparently we have uncovered a factor that should be considered when using such combinations.

[4] It has been learned that the "hexaethyl tetraphosphate" used in this product was actually 20 per cent tetraethyl pyrophosphate, the remainder being other ethyl phosphates.

The Control of Darkling Ground Beetles

JOHN C. ELMORE, *U. S. D. A. Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Several species of darkling ground beetles belonging to the genera *Blapstinus*, *Coniontis*, and *Ulus* (Tenebrionidae), have been known as pests of seedling plants and even larger plants for many years. Vaile (1913) observed a small black beetle, identified as *Coniontis subpubescens* Lec., doing serious damage to beans at Oxnard, Calif. Two species, *Blapstinus coronadensis* Blaisd. and *B. dilatatus* Lec., were reported by Campbell (1922) as damaging small bell pepper plants at La Habra, Calif., by feeding at the base of the stems. Two years later he published (Campbell 1924) an account of plant damage by and control of several species of injurious tenebrionids in the Southwest. The ones mentioned were *Blapstinus rufipes* Csy., *B. dilatatus*, *B. coronadensis*, *B. pimalis* Cys., *B. elongatus* Cys., *Coniontis subpubescens*, *C. muscula* Blaisd., *C. globulina* Blaisd., and *Ulus crassus* Lec.

The adults of these beetles cut off the stems of seedling plants just as they are coming through the ground. The extent of the damage may vary from a few rows at the edge of a field to the loss of large acreage. Replanting of peppers and other field-seeded crops is often necessary because of the damage caused by these beetles. Beans, tomatoes, and many crops commonly transplanted are also subject to attack.

Control measures have consisted of the use of poison bran mash or of paper protectors, and dusting with an arsenical.

At the beginning of the 1946 season growers in southern California complained of damage to seedling peppers the previous year. Early in May the author observed darkling ground beetles damaging pepper seedlings at Talbert, Calif. A comparison of these beetles with identified specimens from the same locality indicated that they were mostly *Blapstinus dilatatus*. From 29 to 46 per cent of the pepper seedlings in one field had been cut off just as they broke through the ground. The beetles were well distributed over pepper fields that had been planted to beans the year before, but they were also moving into seeded pepper fields from former bean fields.

On May 8 an experiment was set up at the corner of a pepper field near Talbert, where the beetles were numerous. Dust mixtures containing 4 per cent DDT fused with sulfur, and 5 and 10 per cent of DDT in pyrophyllite were applied with a hand duster at the rate of 25 pounds per acre. Two days later practically all the dead beetles found were in the first two rows at the edge of the field that had been treated with the DDT-sulfur combination. Apparently this material acted as a barrier, and by contact killed the beetles before they could travel farther into the field. On two 25-foot strips of row, 31, 18, and 48 dead beetles and 4, 3, and 5 living beetles were collected 2, 6, and 12 days, respectively, after treatment. Eighty-nine per cent of the beetles were dead. Since all of the beetles were removed at each count, the beetles seemed to have moved into the dusted area. When alive these beetles are inconspicuous, but when dead they are on their backs and are very noticeable.

A farmer who saw the dead beetles on their backs dusted an 80-acre field of seedling peppers with 5 per cent of DDT in pyrophyllite. The dust was applied with a power duster at the rate of 15 pounds per acre. Beetles were then well distributed over this field, but after 24 hours only dead ones could be found. A few live ones were found 5 days later.

In three 25-foot strips of row, 36 per cent of the plants were destroyed before the dusting and 62 living beetles were observed. After 6 days only 7 living beetles were found. The dead beetles were scattered generally over this area. In the hand-dusted plots, however, the dead beetles were found along the pepper row where the insecticide was more concentrated. It appears that the beetles contacted the poison by crawling through it.

As a result of this pepper grower's success in control, growers of about 700 acres of peppers in Orange and Ventura Counties, California, dusted their fields with 5 per cent of DDT in pyrophyllite for control of the darkling ground beetle. Some of these growers learned that the degree of plant protection was highest when the dust was applied just before the pepper seedlings were due to break through the ground. Many of the same growers were again successful in the use of this control in 1947.—8-15-48.

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Occurrence of Thrips within Tomato Fruits

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During the tomato-canning season of 1941, a cavity harboring thrips was found inside a tomato fruit in the canning factory at Spanish Fork, Utah. After this discovery was made workers examined 691 tomato fruits, taken from the conveyor belt after the fruit had been washed. Each tomato was cut in half or quarter and examined for thrips. Sixty-six tomatoes, or 9.5 per cent, were found to contain cavities that were harboring or had harbored thrips, as evidenced by the calloused and darkened tissue. How, when, or where the thrips got into the tomatoes was not known. However, it was common belief that the cavities were caused by thrips hatching from eggs deposited in the fruits when they were small.

To learn more about the thrips problem in tomatoes, the United States Department of Agriculture and the Utah Agricultural Experiment Station undertook cooperative studies in 1942.

Several thousand green and ripe fruits were taken from the field during the 1942 season, cut lengthwise in thin slices, and examined under a binocular microscope for cavities and thrips.[2] About 10 per cent of the tomatoes contained cavities, of which 70 per cent were open to the blossom end of the fruit. During the canning season that year, many tomatoes with catfaces or large stylar scars were selected, and others were taken at random from the conveyor belt in the factory after they were washed. These fruits were cut in thin slices and examined for cavities and thrips. Twenty-seven per cent of the selected fruits contained cavities capable of harboring thrips, but only 10 per cent of the fruits taken at random contained cavities, and few such fruits had large stylar scars. Thus, many of the cavities are associated with fruits having large stylar scars.

At weekly intervals during the period of fruit setting each year from 1943 to 1946, inclusive, green tomatoes of all sizes, as well as some ripe fruit, were cut in thin slices and examined under a binocular microscope to determine when and how the thrips entered the cavities. The species of thrips found in the tomato fruit were *Thrips tabaci* Lind. and *Frankliniella moultoni* Hood.[3] For this study, the tomatoes were taken from replicated plots of the Stone variety, as it is the predominant strain used for canning in Utah. They were cut in thin slices and were classified according to diameter (Table 1).

Except in 1943, 25 fruits, when available, of each class were picked from each of four plots in the field on each date, and were sliced crosswise and examined. In 1943, 25 fruits of all sizes were taken from individual plants and sliced lengthwise. Tomatoes were not ripe until late in the season; consequently, more green fruits than ripe ones were examined.

Analysis of the data showed that there were just as many cavities in the small fruits as in the large, and just as many the first year as the last. On an average, 18 per cent of the tomatoes contained cavities.

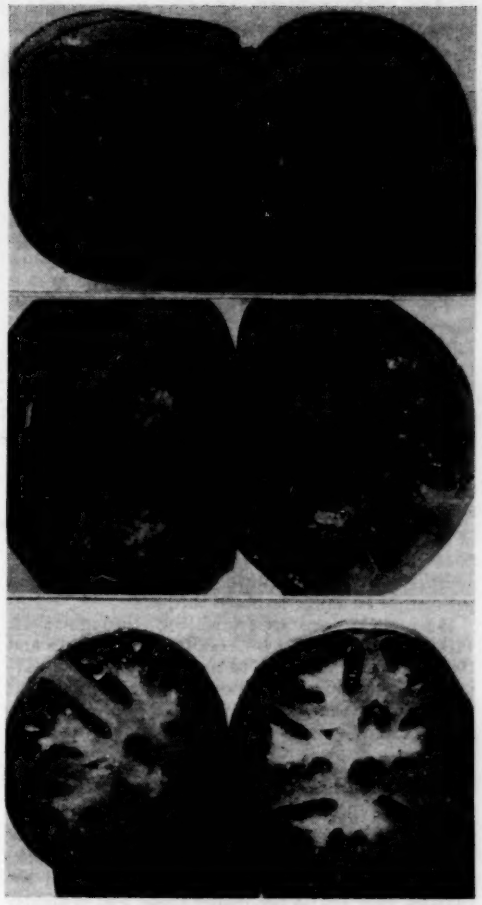

FIG. 1.—Three types of cavities in tomatoes: (A) Cavity in the center of the fruit that had been open to blossom end but was closed at the time of examination; 53 thrips were found in the cavity; (B) seed pocket open to the blossom end and containing thrips; (C) cavity harboring thrips in the solid tissue of the fruit.

The cavities varied in size and shape. Some were about the size of a pinhead, whereas others were an inch or more in diameter. Some of them were round and others long. A few were shallow and near the blossom end, but most of them went deep into the fruit. Cavities occurred both in the solid tissue of the fruit and in seed pockets. Figure 1 shows cavities of various sizes and shapes found at different locations in the fruit.

The percentage of cavities open to the outside for the various-sized fruits was determined. Analysis of the data showed just as many open cavities in the small fruits as in the large ones. It also showed that there were as many cavities one year as another. Approximately 71 per cent of the cavities were open to the blossom end of the fruit. The others had darkened and scarred tissue connecting each cavity with

[1] H. E. Dorst assisted in various ways during the last year of this study, and Mervin W. Nielson and Stephen L. Wood also helped in gathering the data reported here.

[2] L. B. Reed reported this work at a meeting of Entomological Society of Washington in January 1943. (Ent. Soc. of Wash. Proc. 45: 56.)

[3] Identified by J. C. Crawford, U. S. Bureau of Entomology and Plant Quarantine.

the blossom end, indicating that at some time during the development of the fruit the cavities had been open. Some of the passageways were open part way to the cavities, but the developing fruit tissue had pressed the walls together, sealing the cavities off from the outside. Thrips had become sealed in many of the cavities by the closing of the passageways, particularly in the ripe fruit, where the tomato tissue was more pliable than in the green. Many of these thrips had produced a brood while trapped. One or more adults were found in a closed cavity along with as many as 73 nymphs. In a few tomatoes, the developing tissue had pressed the walls of the cavity together, killing the thrips that were inside.

The percentages of cavities harboring thrips and the number of thrips per 1000 fruits were determined and tabulated. Analysis of the data showed that there was a difference in the number of cavities harboring thrips in the various sizes of tomatoes and in different years. It also showed a difference in the number of thrips per 1000 fruits in the various sizes. Few thrips were found in tomatoes smaller than 0.5 inch in diameter. The number of cavities harboring thrips increased as the size of the fruit increased. More thrips were found in ripe than in green fruits of the same size. More thrips were found in 1945 and 1946 than in other years. Of the fruits containing cavities, 15 per cent were harboring thrips. Two per cent of all fruits harbored thrips.

During the seasons from 1943 through 1946, 11,119 tomato fruits were examined for cavities and thrips. Of that number, 18 per cent contained cavities. The small fruits contained as many cavities as did the large ones; however, there were twice as many cavities in fruits with catfaces and large stylar scars as in fruits with small blossom ends. Of the 314 cavities harboring thrips, 188 were open. Of a total of 665 thrips found, about twice as many per cavity were in closed cavities as in open ones.

The authors believe that the development of cavities is a natural process accompanying the growth of the fruits. Once the thrips entered the cavities, they fed on the tender tissue and evidently laid their eggs. Apparently, during the process of growth the enlarging tomato tissue often pushed the cavity walls together in places and sealed the thrips inside. However, some adults evidently crawled back out after laying eggs, before the passage was sealed off. Adults and nymphs were found in the sealed-off cavities of some fruits, and in other fruits only nymphs were present. Mixtures containing 3, 5, and 10 per cent of DDT in several applications gave measurable reductions. However, rotenone, pyrethrum, nicotine, calcium arsenate, and DDT failed to give practical control. Selection of varieties and strains having few cavities seems to offer the best hope for control.

A Hollyhock Leaf Miner New to North America

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Between June 6 and June 15, 1948, the writer noticed small leaf-mining buprestids sunning themselves and mating on the upper surface of hollyhock leaves in the backyard of a residence in Rutherford, New Jersey. Specimens were collected and identified as *Trachys pygmaea* (Fab.), an Old World species not previously reported from North America. Its Old World distribution includes southern and eastern Europe, Asia Minor, and North Africa, where it has been recorded as a leaf-miner in hollyhock, *Althaea rosea*, high mallow, *Malva sylvestris*, and dwarf or running mallow, *Malva rotundifolia*.

Adverse weather conditions and limited time did not permit observations on the habits of the species in New Jersey. However, Leprieur (1861) has reported on studies made in Algeria and stated that the eggs are placed singly on the under surface of the leaf, usually near the edge, beneath a white protective covering about half a millimeter in diameter. After a few days incubation, the egg hatches and the larva penetrates the leaf epidermis directly beneath its protective covering. It then feeds between the epidermal layers of the leaf forming an irregular oval mine. In 15 or 16 days the larva pupates in a corner of the mine and in another 8 or 10 days transforms to the adult stage. Leprieur did not mention more than one generation each year, although two or more have been reported for other species in the genus.

Trachys pygmaea may be readily distinguished from other leaf-mining buprestids in our fauna (Nicolay & Weiss 1920, 1923) by its coloration (bright green or blue-green with a brilliant coppery head and pronotum) and by having the antennae free in repose, rather than lodged in a deep groove in the prosternum.

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A Nitidulid Beetle Infesting Sweet Corn

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Nitidulid beetles, *Carpophilus lugubris* (Murr.), have for a number of years caused injury and extreme annoyance by infesting sweet corn ears at Green River (Knowlton 1942),[1] and also in a number of other southern Utah communities. This species also was collected from inside ears of golden bantam corn at North Logan in the fall of 1939. Injury to sweet corn by this pest was noted in Utah County during 1945. Infestation of corn by this species became so serious locally that in 1946, one field of sweet corn at Springville was refused by a canner. Several fields of corn again were seriously infested in this same locality during 1948, being unfit either for canning or market use.

Infestation by this nitidulid beetle has most commonly appeared to follow corn earworm injury. At Springville, Utah, on July 23, 1948, from five to 34 adults and from a few to more than 100 of the dirty-whitish larvae were found within the husks of each infested ear. Larvae of the beetles at this time varied in size from just hatched, to full grown. Nearly all ears of corn which were reaching maturity were at

[1] Knowlton, G. F. 1942. Nitidulidae in corn. JOUR. ECON. ENT. 35: 105.

this time conspicuously infested, in the most seriously infested field. From one to nine larvae were found within each infested kernel. Many small worms were present between the kernels. Infested ears in this field nearly always contained both adult beetles and the whitish larvae. In a slightly later and less severly infested field, nearby, 40 per cent of the ears examined were found to be infested. In approximately 25 per cent of the *Carpophilus* infested ears of sweet corn examined from this patch, which were just approaching good market condition, no sign of corn earworm infestation or injury was found. It appeared that large numbers of the adult beetles had either matured in earlier corn infested with the earworm and then had moved to nearby later corn, or adult beetles breeding in the area had accumulated in such ears and had deposited eggs from which the later infestation arose. These ears of sweet corn, maturing a little later than the corn in the near by earlier patch, often had a serious infestation of small and fewer larger to half grown *Carpophilus* larvae. Several to many adult beetles usually were present wherever larvae were found. The so common occurrence of nitidulid infestations in ears showing no damage by earworm or other apparent cause, suggests that this species may at time of great local abundance become a primary pest of sweet corn.

The Oriental Fruit Fly in Guam

KENNETH L. MAEHLER[1]

A new insect pest, the Oriental fruit fly, *Dacus dorsalis* Hendel, has invaded Guam. Because of its importance from the standpoint of agriculture and Quarantine, it seems desirable to put information regarding its history, distribution, and hosts on record. Judging by recent experiences in Hawaii, where it attacks a long list of hosts (see below), the agricultural interests in Guam should regard this new discovery with considerable apprehension. In Hawaii its depredations have become so serious that the Chamber of Commerce of Honolulu has appealed to Congress for $100,000 a year to combat it and related fruit flies.

HISTORY.—A report by Teiso Esaki[2] states that "The orange fruit fly, *Chaetodacus dorsalis* Hendel, was introduced most probably from Okinawa, Ryukyu Islands, into Saipan some fifteen years ago, and is very injurious not only to Citrus but to many other fruits also." R. G. Oakley (1946,)[3] states that "the larvae of *Dacus dorsalis* Hendl. were found on Rota, Saipan, and Tinian, infesting fruits of avocado, breadfruit, guava, mango, papaya, soursop, and tropical almonds. . . . Of Rota mangoes examined, for example, about 50 per cent of the fruits were attacked, about 25 per cent of the mangoes on Saipan and Tinian were likewise found attacked, and 100 per cent of the mature green avocados examined from two Saipan trees were infested." At that time Oakley did not find the fly on Guam. In fact, as late as October 1947, C. E. Pemberton stated that he was unable to find the fly on Guam.

DESCRIPTION.—The Oriental fruit fly is slightly larger than the house fly. Its color is predominantly yellow with dark markings on the thorax; the abdomen is marked with a "T," formed by the juncture of a transverse band and a median, sometimes broken stripe down the dorsum. Its clear or hyaline wings readily separate it from the melon fly, *Dacus curcurbitae* Coq., whose wings have darkened areas.

The larvae or maggots are white at first and then yellow slightly as they mature. They are easily recognized as fruit fly larvae by their habit of doubling up and jumping about if disturbed.

BIOLOGY.—The female lays her eggs beneath the skin of the selected host. The eggs soon hatch and the larvae spend their entire life protected within the fruits. Casual inspection will not tell whether or nor a fruit is infected. The "sting marks" are easily overlooked as the fruit develops. Usually ripening fruit is selected by the female for oviposition. Occasionally, green bananas may be stung.

When the larva has reached maturity, it usually leaves the fruit and drops to the ground, where it buries itself. Here it forms a hard puparium in which it changes an adult fly.

SURVEY.—The problem to determine the presence of *Dacus dorsalis* Hendel on Guam was approached from two aspects. First, an attempt was made to examine all possible hosts for the larvae and attempt to rear the flies. Second, a trapping program was carried on, using citronella as bait.

The first survey consisted in collecting as much suitable host material as possible, examining it carefully for larvae, and as a secondary check putting it in breeding cages in an attempt to rear out flies that the examination may have missed. These attempts yielded negative results with the following exception. On December 16 a survey of host material was initiated. On December 19, near Agana, in the town of Sinajana a number of banana plants were being examined. Upon one plant was found a hand of black, partially desiccated fruit, which had been allowed to mature and spoil on the plant. A mature fruit fly larva wriggled out as one of the fruits was opened. Four mature larvae were collected, which pupated. On December 29 two flies emerged, and these specimens were tentatively identified as *Dacus dorsalis* Hendel. They were sent to the Bureau of Entomology and Plant Quarantine for confirmation, and there the determination was verified for this first record of the fly on Guam.

The technique used in trapping the flies was simple. The trap consisted of a celluloid vial filled about a third full of water, with a thin film of citronella on top. The tube was attached to a tree or convenient object. A white label behind the tube made it easier to locate. The tubes were placed about 5 feet off the ground in the semi-shade. Before the survey was attempted on Guam, the effectiveness of the trap was checked on Saipan, where flies were known to occur. The male flies were attracted to the citronella, entered the tube, fell into the water and were unable to extricate themselves. By means of this device about 500 flies were collected on Saipan in 4 hours. It is estimated that these traps are effective for from a quarter to a half mile.

HOSTS.—When we consider that the fly has occurred on Saipan for 15 years, it seems inconceivable that it had not been introduced to and become established on Guam, 125 miles away, with three intervening islands on which the flies are found. Undoubtedly many opportunities had presented themselves, in the movement of produce during and after the war, for the fly to be carried from Saipan,

[1] Published by permission of the Insect Control Committee for Micronesia, Pacific Science Board, National Research Council.

[2] Teiso Esaki, A preliminary report on the entomological survey of the Micronesian Islands under the Japanese Mandate, with special reference to the insects of economic importance. Sixth Pacific Science Congress of the Pacific Science Association, Proceedings IV: 407–415, 1940.

[3] Richard G. Oakley, Entomological observations in the Marshall, Caroline, and Mariana Islands, U. S. Commercial Company, Economic Survey, Honolulu, 1946.

Tinian or Rota to Guam. It was not being presumptive, then, to assume that the fly had been introduced into Guam. Why then had it not increased in numbers as it had in other situations? There are two possible reasons why the fly is not abundant on Guam. First, there may be some parasite or predator which is keeping it down in numbers. Second, the host sequence, that is, the availability of food, may be so interrupted as to allow no population build-up.

Following the second line of reasoning, a study was undertaken of the possible hosts of the fly. Breadfruit were just coming into season. An occasional tree might produce an off-season fruit, but here was no sustained food supply. Bananas, although they occur throughout the island, seldom had ripe fruit on them. If the flies were ovipositing on bananas, the larvae probably were being ingested before they could complete their development. Papayas occurred in large groves along a good part of the highway system of Guam. They bore fruit throughout the year. This seemed a logical reservoir host. But investigation of hundreds of plants distributed over the island yielded not one larva. A good portion of the plants were male and bore no fruit at all. Other plants, which bore from 40 to 80 fruit, seldom if ever had any ripe fruit on them. Going through a papaya grove and looking for ripe fruit proved an enlightening experience. The few fruits which at a distance seemed ripe and intact, upon closer examination showed that the inside had been eaten out entirely by rodents, birds or, perhaps, fruit bats.

One factor, which was immediately apparent to anyone coming from Hawaii, was the absence of guavas on Guam. The abundant guava on Oahu, T. H., serves as an excellent host for the fly. On Guam the guava is practically non-existent. Here was an important reservoir host lacking from the picture. The few plants I chanced to find were small and stunted. Referring to Swezey's work,[4] I found that a small tortricid moth, *Spilonata holotephras* Meyrick, was held responsible for the lack of guavas on Guam. Here was an insect that could well be used to control this reservoir host of *Dacus dorsalis*.

Eliminating the hosts, one by one—breadfruit, banana, papaya, guava—it became increasingly evident that the fly had found a host which I had overlooked. This was born out later when a number of traps in the Talofofo area yielded a number of specimens of the fly. Checking this region, it was found that the flies had established themselves on custard apple, *Annona reticulata*, which was growing in a semi-cultivated condition among the road.

The following list of Hawaiian hosts of the fly, as compiled by the Fruit Fly Investigation Laboratory at Honolulu, is included for information.

SUMMARY.—The Oriental fruit fly (*Dacus dorsalis* Handel) was first collected on Guam on December 19, 1947. The determination of this fly has been confirmed by competent authority. It has been reared from bananas on Guam, but it is mainly sustained at this time of year by the custard apple. Because of birds, rats and fruit bats, which attack the fruit, papaya does not seem to constitute an important host. Guavas, which form a major reservoir host for this fly in Hawaii, are rare on Guam. During the breadfruit season, we should expect an increase in the fly population, unless it is being held in check by some parasite. Further investigations will be carried on.

[4] O. H. Swezey, A survey of the insect pests of cultivated plants in Guam. The Hawaiian Planters' Record, 44 (3): 151–182, 1940. (See p. 175.)

Hosts of *Dacus dorsalis* Hendel in the Hawaiian Islands (Compiled by The Fruit Fly Investigation Laboratory, Honolulu).

Apple (*Pyrus malus*)
Averrhea carambola
Avocado (*Persea americana*)
Banana (*Musa cavendishii*)
Bitter melon (*Memordica charantia*)
Breadfruit (*Artocarpus communis*)
Canistel (*Lucuma nervosa*)
Chebula (*Terminalia chebula*)
Cherry, Surinam (*Eugenia uniflora*)
Coffee berries (*Coffea arabica*)
Cotton (*Gossypium* sp.)
Damson plum (*Chrysophyllum monopyrenum*)
Date, Arabian (*Phoenix dactylifera*)
Fig (*Ficus carica*)
Flacourtia jangomas
Guava, comon (*Psidium guajava*)
Guava, strawberry (*Psidium cattleianum littorale*)
Kamani (*Terminalia catappa*)
Lime (*Citrus aurantifolia*)
Litchi (*Litchi chinensis*)
Loquat (*Eriobotrya japonica*)
Mabola or velvet apple (*Diospyres discolor*)
Mango (*Mangifera indica*)
Minusops elengi (Spanish cherry)
Mock orange (*Murraya exotica*)
Mountain apple (*Eugenia malaccensis*)
Natal plum (*Carissa grandiflora*)
Orange, sweet (*Citrus sinensis*)
Papaya (*Darica papaya*)
Passion fruit (*Passiflora edulis* var. *flavicarpa*)
Passion fruit (*P. subpultata* or *P. foetida*)
Peach (*Prunus persica*)
Pepino (*Solanum muricatum*)
Persimmon (*Diospyros kaki*)
Pimenta acris (Bay rum tree)
Pimenta officinalis (allspice)
Pithecollobium dulce (Guaymochil, opiume, Madras thorn, etc.)
Plum (*Prunus domestica*)
Polyalthea longiflora
Pomegranate (*Punica granatum*)
Pomolo (*Citrus maxima*)
Prickly pear (*Opuntia vulgaris*)
Rose apple (*Eugenia jambos*)
Sea-grape (*Coccoloba uwifera*)
Sour orange (Citrus aurantium)
Soursop (*Annona muricata*) & Custard apple (*Annona reticulata*)
Tahitian chestnut (*Inocarpus edulis*)
Tomato (*Lycopersicon esculentium*)
Wi apple (*Spondias dulcis*)
Ylang ylang (*Artabotrys odoratissima*) (*Cananga odorata*)
White sapota (*Casimiroa edulis*)
Mulberry (*Morus nigra*)

RECOMMENDATIONS. Inasmuch as the Oriental fruit fly occurs on Guam and is fairly well distributed there, the prohibition of the shipping of fruit from the northern Marinas into Guam no longer seems justified. The recommendation of the Insect Control Committee for Micronesia that the prohibition remain in force was made prior to the discovery of the fly on Guam. It is now recommended that fruit from the northern Marianas (Saipan, Tinian and Rota) be allowed to enter Guam, but that shipment of fruit be prohibited from these islands and Guam to other parts of the Trust Territory, where the fly is not known to occur.

The Liberation of *Hippodamia convergens* in the Yakima Valley of Washington, 1943 to 1946

MELVILLE H. HATCH AND CHERIE TANASSE,
University of Washington, Seattle

About 1910 the practice developed in California of transporting hibernating masses of *Hippodamia convergens* Guer. from the mountains to the truck gardens, where they were supposed to be beneficial in combating aphids (Carnes 1912). Free delivery was provided by the express company and, despite the 50 or 75 per cent mortality, large numbers of the growers were enthusiastic in support of the practice. This enthusiasm was not, however, very deep seated, because, when the government took over the express business in 1918 during World War I and suspended the free transport of the beetles, the growers were not sufficiently interested to pay the transportation charges themselves.[1] Meanwhile W. M. Davidson (1919, 1924) showed that upon release the beetles scattered so rapidly that insufficient concentrations of beetles were present to be of any value in aphid control.

The fame of the attempted control, however, survived its scientific discrediting, and Prof. E. O. Essig writes me that growers in certain parts of the San Joaquin Valley and in the Sierra foothills have frequently gathered private supplies of beetles and there has been a limited but decreasing private sale. An account of such a private distribution of lady-beetles along the eastern slope of the Cascade Mountains in Washington is given by Wilson (1925). In Yakima, moreover, one of us (C.T.) is informed that one of the growers secured lady beetles for himself every year between about 1924 and 1936. Also it appears that some of the growers in the vicinity of Wenatchee have been purchasing beetles from a man in Juliaette, Idaho, at the rate of 6 or 8 dollars a quart of 8000 to 10,000 beetles.

With the insecticide shortage in 1943, incident to World War II, the hop growers in the Yakima Valley were deprived of their supplies of nicotine spray and turned to the use of beetles as a possible substitute. Supplies of *Hippodamia convergens* were secured from Mr. L. W. Higgins of Dobbins, Yuba Co., California, who had been supplying California growers with beetles for some years. He stored the beetles in bags, about two gallons per bag, keeping them for as long as 4 months in storage at 40° to 45° F. without over a 10 per cent loss, and has shipped beetles to growers in southern California, Arizona, Georgia, Florida, and New Jersey. The beetles for the Yakima Valley were trucked north in bags freely suspended from racks, and distributed by the Washington State Hop Producers, Inc. and the county agent at $2.50 per gallon. Some growers purchased as few as 3 or 5 gallons of beetles, others as many as 80 gallons in a single season, and some were released in orchards as well as in hop fields. In 1946, when fewer beetles were used than previously, a total of 1160 gallons were liberated in the vicinity of Yakima. In part, at any rate, the use of the beetles became a community project and many growers used them for that reason rather than from any personal conviction as to their utility. Some of the growers, however, felt considerable confidence in the efficacy of the method. With the passing of war conditions reliance upon insecticides became reestablished and no extensive importation of beetles was reported in 1947. The matter is of interest, however, in showing the persistence of a scientifically unjustified attempt at biological control 20 years after its disqualification.—10-15-48.

[1] E. O. Essig *in litt.*

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Apple Maggot Emergence in Western New York

RALPH G. PALMER, *Rochester 7, N. Y.*

For some years it has been assumed that apple maggot flies started emerging in western New York in late June or early July and reached the peak of emergence about July 15. Because of some indication that this was not the case the writer set up in 1948 an emergence cage over an area seeded with maggot-infested Wealthy apples late in 1947. When no flies had emerged by July 15, diggings were made adjacent to the cage and some pupae found and placed in soil in a glass jar at the writer's field office some miles away from the emergence cage.

On July 28 a single fly had emerged in the glass jar and on July 29 the emergence cage was visited and 30 apple maggot flies collected. The collection of apple maggot flies in the cage is as follows:

July	29—30	August	6—16
July	30—26	August	9—14
July	31—24	August	10— 1
August	2—21	August	13—10
August	4—32	August	17— 6
		August	20— 2

On August 20 the writer walked slowly around the tree under which the cage was located and casually counted 21 apple maggot flies on the foliage and fruits. The fruit of the previous season on this tree had not been harvested because of maggot infestation.

Because of other duties, and absence from the area, no further counts were made but it is believed that very few flies emerged after the last record above. It was planned to get a final record late in August but a rent in the cage was found at this time and no record could be made.

It was evident that the apple maggot protection applied in late June and early July was inadequate at the time of the heavy emergence around the first of August. Considerable fruit infestation is reported in this area in 1948. Seedings have been made and emergence records will be made in 1949. Apparently it will be necessary to check apple maggot fly emergence each season in order to time spray applications to control this pest.

Aphid Injury to Wheat[1]

C. A. SUNESON AND S. F. BAILEY

For two successive years, 1946 and 1947, the wheat variety Mentana (Italian) growing in yield test plots at Davis, California, has suffered 70 to 80 per cent breakage of stems at basal internodes late in May and prior to full maturity. The breakage has been facilitated by wind, but the primary cause appears to be aphids. During both years, aphids have been observed in fair abundance early in April throughout the cereal breeding nurseries, but the populations were soon decimated by predaceous cocinellids. The evidence suggests that in the variety Mentana, aphids are protected from their predators by congregating between the stem and leaf sheath on lower internodes. Here, their feeding zone is more or less restricted. Contingent upon their restriction, concentration, and persistance, various malformations on one to three of the lower internodes result as in figure 1, (left). These range from enlargement and moderate stem distortion to constriction and kinking. It is the latter type of injury which results in breakage by the wind. Presumably the kink is formed by greater growth on the open side of the stem. Contiguous to the constricted area there is always evidence of recent or actual abundance of aphids. Live aphids taken from such distorted stems after the first observed breakages in 1947 were identified by E. O. Essig as *Rhopalosiphum prunifoliae* (Fitch).

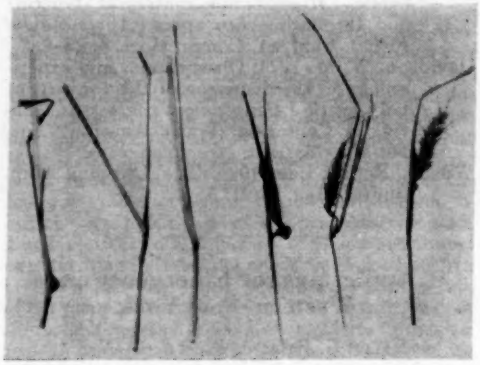

FIG. 1. *Left.* Examples of aphid injury to lower internodes of the wheat variety Mentana. *Right.* Examples of aphid injury ("stem distortion") to top internodes of the wheat variety Baart.

Previous reports on the life history (Baker & Turner (1919), Essig (1926), and Palmer (1939), of this aphid have not described this type of injury although the insect is known to occur commonly on wheat, Patch (1938). Davis (1914), however, wrote that "During the summer this aphis usually feeds on the under surface of the leaves, on the stems, and in the axils of the leaves—seldom in the grain heads as does *Macrosiphum granarium*." The injury here described on the variety Mentana is relatively rare in other wheat varieties.

A second type of aphid injury characterized by stem (and sometimes leaf) distortion above the top node has not been of economic importance in California because it occurs only on occasional culms. It is discussed here primarily because Blodgett & Schultz (1946) failed to associate it with aphids and reported it as being "perpetuated from one season to the next by seed." Examples of this type of injury in the variety Baart in California in 1947 are shown in figure 1, (right). The injuries range from a slight shortening or bowing of the stem above the top node, to extreme shortening and twisting of the upper stem with dwarfing of the spike. In this case too, the injury appears to result from persistent concentrated feeding by aphids. If it were more general, yields would be reduced materially. The senior author made numerous observations and field notes in commercial fields of winter wheat in Oregon, Washington, and Idaho in 1944, just prior to harvest. The incidence of "stem distortion" in that area in 1944 was greater than has ever been noted in California, but the plant distortions were of the same type as those illustrated in figure 1, and there was abundant residual evidence of earlier aphid activity on the affected culms. In our observations of stem distortion the natural enemies apparently have prevented aphid populations from attaining the concentrations and persistence reported by Parker (1916).

The various types of aphid injury to wheat considered or reviewed herein suggest that the injury is purely mechanical. The more numerous and persistent the aphids, the greater the malformation. The observed susceptibility of the variety Mentana to aphid attack and resultant breakage at the lower internodes, makes it unsuited for commercial growing in California.

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Are Entomologists Too Specialized? Training for Entomologists

Are entomologists becoming too restricted or specialized in their research? If so, is this good for the individual and the Science of Entomology?

I was one who lived in an age when the entomologist was expected to conduct research and give advise on any problem which developed. When I was given my first position with Doctor Forbes in 1907, as entomologist for northern Illinois, and with headquarters in Chicago, my problems included field crop pests, shade tree insects, greenhouse insects, truck garden insects, insects in relation to health, and whatever else might come up. Thus I obtained a wide experience of greatest value in years to come.

From such general problems I changed to more specific problems, cereal and forage insects. Somewhat more restricted but still a rather wide field of research. Then to a more restricted problem, the Japanese beetle. But soon thereafter I affiliated with state experiment station work where I had the privilege, and it was a privilege, to return to a variety of problems.

As I look back over my career as an entomologist, I realize I was unusually fortunate in being able to maintain activities in the entire field of entomology and at the same time develop a personal "side line," the taxonomy and bionomics of the Aphididae and Scarabaeidae.

In many respects, from the standpoint of the individual and the science, it seems unfortunate that so many, upon leaving scholastic training, must accept positions where they are subjected to some specialized field, or even some single phase of a single insect problem. Certainly young men just completing scholastic training would be more valuable for specific problems or specific phases of single problems if they had a few years training in general research problems. I do not know how this situation can be remedied unless the older entomologists in charge of projects be more lenient in providing a broader scope of activities for the younger men.

There are two factors, it seems to me, which are largely responsible for the present situation. Let us study the situation. In general, experiment stations, because of small finances, provide opportunities for general projects which allow a fairly broad experience. In a few cases experiment stations are able to provide opportunities for individual projects. Industry has provided many opportunities for entomologists and, for the most part, the problems are rather specific, giving less opportunity for a general development in the broad field of entomology. The federal Bureau of Entomology, and Plant Quarantine provides the most restricted opportunities because they are provided with large funds for specific problems which necessitates restricted problems for individuals wherein one has little opportunity to develop a broad knowledge of economic entomology and for advancement to positions requiring a broad knowledge and understanding of the field of entomology.

The second factor which may well be stressed is what we might call "unionism." This second factor was inaugurated by the federal Department of Agriculture. Double pay for time in excess of 40 hours increased salaries. Then, salaries were increased with no work on Saturday. Experiment stations are beginning to follow suit. Federal workers were given to understand that if they appeared for work on Saturdays they were committing a crime. Thus, a foreign representative was to be entertained by the station on Friday and the federal representatives on Saturday. The federal representatives advised that they could not work on Saturday and asked the station to take over the duties for Saturday. We were glad to do this. But isn't this an asinine situation.

Have entomologists become so unionized that they cannot entertain foreign representatives on Saturday or, if necessary, even Sunday?

I was taught to understand that insects did not take off Saturday or Sunday or holidays. In other words, if the problem required attention at any time, the entomologist gave no attention to an 8-hour, 5-day week. The situation that has developed is especially harmful to entomologists just starting in entomology. The present situation gives new entomologists a wrong idea of the science. We need more appreciation and love of our science and less commercialization and unionism. Briefly then, we still have laboratories where results of achievement are recognized, but too often entomology has become a routine where work begins at a certain hour and stops at a certain hour, regardless.

Even with the conditions just reported, the individual entomologist with initiative has the opportunity, if he realizes it, of becoming a recognized authority in some phase of entomology, especially in the field of taxonomy.

S. A. ROHWER

BOOK REVIEW

A TEXTBOOK OF ENTOMOLOGY, by Herbert H. Ross, Systematic Entomologist, Illinois State Natural History Survey; Professor of Entomology, University of Illinois. 532+viii pp. Octavo. 1948. John Wiley & Sons, Inc. New York Chapman & Hall, Ltd. London. Price $6.00.

American textbooks in entomology have been distinguished by their high quality rather than by mumbers and variety. Dr. Ross' addition to the series has maintained the traditional quality and, at the same time has approached the subject from a thoroughly independent point of view. By careful selection and concise treatment he has succeeded in giving comprehensive discussions without requiring a volume which cannot be covered in a single college semester. The arrangement is logical. First a discussion of the history of entomology, especially that of American entomology, which briefly but competently summarizes that phase of the subject. This is followed by a discussion of the Arthropoda which establishes their place in the animal kingdom and the scope of the branch and integrates the insects with their nearest relatives. Chapters on the anatomy of the insects, external and internal, follow. In these the author succeeds in giving an entirely adequate picture of the essentials of insect structures necessary for the intelligent comprehension of descriptions of insects. This is followed by an equally satisfactory brief treatment of the internal structures. The latter chapter is supplemented by a discussion of insect physiology, which includes a paragraph on behavior. all so presented as to suggest interpretations of insect reactions and all potentially useful in the study of any phase of insect activity.

Little attention has been given by most teachers to insect embryology largely, perhaps, because of lack of assistance from current texts. Dr. Ross, in his discussion of the life cycles of insects has started with a discussion of embryology and has followed with a survey of metamorphoses and the variety of different types of development to be observed in the several stages of different types of insects. Among the latter may be mentioned the social insects, aquatic forms, alternation of generations and such interrelationships of insects and plants as gall formation.

Taxonomy does not constitute as great a proportion of this text as it does in most others but it is still very adequately treated. It may well be said that the author has used great discrimination in the selection of material to be omitted to keep the book within the desired scope. It is not apparent that the omissions have included any essentials. The orders, conforming closely to the traditional list, but with clarifications, especially among the primitive groups, have been clearly described and well illustrated. The families discussed are well keyed and supplementary descriptions and discussions serve to bring out the importance of the economic forms and at least to mention many that are of interest from other points of view. Innovations in the text include a summary of the geologic history of insects and a section devoted to insect ecology. The discussions of ecology insect control problems by pointing out the necessity for an understanding of ecology in approaching the problems of control. The analysis of economic problems begun in the discussion of ecology is continued in a chapter devoted to control considerations. In this chapter mention is made of many of the insects and insect groups which are of direct importance to man and modern methods of insect control are described. Fundamentals are considered here rather than the constantly changing details of insecticides and their methods of application.

The book is well illustrated throughout, illustrations being drawn from a wide variety of sources including especially the material at the author's command in the collections of the Illinois State Natural History Survey. The volume is attractive in appearance and well printed and edited. As a textbook it will not scare off the student by its imposing size. Rather, the student will feel that he has a book which he may well hope to master while the instructor will be freed from the former necessity of selecting limited portions from a text which the majority of his students feel is beyond their needs.

OBITUARIES

Clell Lee Metcalf, 1888-1948

Clell Lee Metcalf, the seventh and youngest son of Abel Crawford Metcalf and Catherine Fulmer Metcalf, was born at Lakeville, Ohio, on March 26, 1888. He carried on studies with the Home Correspondence School of Springfield, Massachusetts, from 1903 to 1906, and entered the high school at Wooster, Ohio, graduating in 1907. In the same year, he enrolled as a student at Ohio State University. Here he received the degree of bachelor of arts in 1911 and the degree of master of arts in 1912. Holding the George Emerson scholarship, he pursued advanced graduate study at Harvard University, securing the degree of doctor of science in 1919.

Doctor Metcalf's interest in natural history was aroused very early in life when a boy on his father's farm amid the hills and lakes of Ashland County. As a consequence, he went to his state university with the definite purpose of training for entomological work. This early decision coupled with his excellent native ability and capacity for much work opened the way for a variety of positions in his chosen field. He served successively as: assistant in Zoology and Entomology from 1910 to 1912; assistant in the University's Lake Laboratory at Cedar Point in the summer of 1912; assistant entomologist in the Department of Agriculture of North Carolina from 1912 to 1914; assistant professor of Entomology at Ohio State from 1914 to 1919; consulting entomologist at the Agricultural Experiment Station of Maine in the summers of 1915, 1916 and 1917; instructor in biology at Cornell University in the summers of 1918 and 1919; professor at Ohio State

University in 1920 and 1921; investigator on blood-sucking flies in the Adirondack Mountains of New York in the summer of 1929; and professor of Entomology and head of the department at the University of Illinois from 1921 to February, 1947, when failing health compelled him to relinquish his active duties. He died on August 21, 1948, at the age of 60 years. Surviving are his wife, Cleo Esther Fouch Metcalf, whom he married in 1908, two sons—Doctor Robert Lee Metcalf, situated at the Citrus Experiment Station, Riverside, California, and James Richard Metcalf, currently a student in agriculture at the University of Illinois, and five brothers, among them the well-known entomologist, Dr. Zeno P. Metcalf.

Always a prodigious worker, Dr. Metcalf carried a full schedule of teaching in addition to administrative duties, yet found time, much of it in the late hours of night, to accomplish extensive writing. A list of publications found in his files embraces but 30 titles, but a number of these are quite lengthy papers and exhaustive books. The publications are of three quite distinct sorts—research papers, service articles, and books. The series of research contributions appeared largely from 1911 to 1917, and dealt chiefly with the bionomics, ecology, description and classification of the dipterous family Syrphidae. He was among the first American entomologists to employ the genitalia of male insects as a basis for distinguishing species. His essay on "Genitalia of Male Syrphidae," prepared as a doctor's thesis, appeared in 1921, after the series of articles devoted to the Syrphidae of Ohio, North Carolina, and Maine. Also several research papers, concerned with Syrphidae and a miscellany of other insects, were published.

Among the more voluminous published service treatises were his lecture on "Warfare Against Insects," given on invitation of the Entomological Society of Ontario, and essays on "Insects and Insecticides" (Amer. Florist) and "Progress in Spraying and Dusting Methods During the Past 75 Years" (Trans. Ill. St. Hort. Soc.). This shift toward writing on insect control was paralleled by studies in the area of medical entomology, which received expression in four articles, two of them having been published jointly with W. E. Sanderson. In addition, Doctor Metcalf was often in demand for lectures to local groups and at other colleges. Among these, the lecture entitled "Insects Take a Look at Man" was given repeatedly and with unusual effect.

The third type of writing is represented by three books in co-authorship with the late W. P. Flint, namely *Destructive* and *Useful Insects*, 1928 and 1939; *Fundamentals of Insect Life*, 1932, and *Insects, Man's Chief Competitors*, 1932. With his brother, Zeno Metcalf, he published "A Key to the Principal Orders and Families of Insects," richly illustrated and widely used in teaching entomology in American Schools since 1928. A second revision of *Destructive and Useful Insects* was in progress when Doctor Metcalf became incapacitated.

In his twenty-five years at Illinois, Doctor Metcalf gave courses of instruction in beginning entomology, insect control, medical entomology, and the bionomics of insects, and directed the investigations of many advanced students. As a consequence of his reputation as a teacher, graduate students from many states and Canada, as well as Illinois, came to work under his direction. He truly loved to teach, and this eagerness persisted and was frequently uttered until his declining health reached an advanced state. In several semesters, his lectures were broadcast over the University's radio station WILL. Like his writings, particularly the books, his instruction was characterized by completeness of treatment, clarity and vigor. The class sessions typically began with an unannounced written quiz or a series of snappy oral questions that kept students alert, shifting then into a lecture richly illustrated with precise drawings, specimens, charts, and lantern slides.

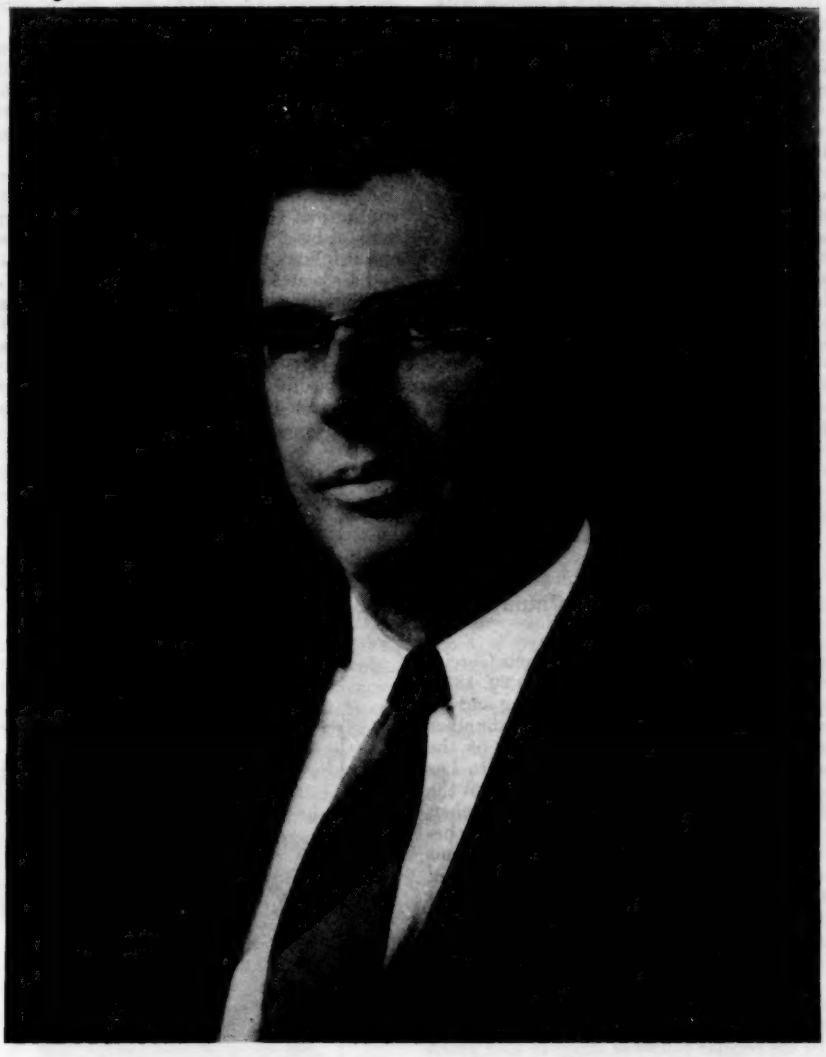
His capacity for achievement also expressed itself in the growth of the material equipment of the department. The files of lantern slides and the series of wall charts were multiplied many times during his administration, and the sets of insect specimens mounted in sealed tubes or on slides for use in some undergraduate courses now exceeds 500. Instruments and facilities of other kinds required by the staff and graduate students for teaching and research were provided with similar liberality.

Doctor Metcalf was a member of several scientific societies—the American Association for the Advancement of Science, the American Association of Economic Entomologists, the Entomological Society of America, Sigma Xi the Illinois Academy of Science and Gamma Sigma Delta. In 1920, he was elected a fellow of the Association for the Advancement of Science and the Entomological Society, and served as secretary-treasurer of the latter from 1922 to 1926 and as president in 1934. In the scholastic year 1937–1938, he occupied the presidency of the Illinois Chapter of Sigma Xi.

But professional interests did not monopolize his time, for he gave energetic leadership to several local community organizations, having served on the directing bodies of the Boy Scouts of America, the Urbana Golf and Country Club, the University Y.M.C.A., the Urbana Rotary Club, and the Trinity Methodist Church of Urbana. He was also affiliated with the Dial Club and the Chaos Club, local organizations within the University of Illinois.

Slight of physique, with flashing dark eyes and seemingly inexhaustible energy, Doctor Metcalf will be remembered for his serious interest in Entomology and his department, the high goal of performance he set for himself and implied for his colleagues and students, the sincerity and cordiality of his human contacts, his staunch defense of what he believed to be right, his zeal for every good cause that won his attention, and his devotion to church and family. A vigorous proponent of entomology, he long since earned a national and international reputation through his writings and teaching. His family, his friends and fellow entomologists, his community and the ideal causes which he served out of a very full life, have lost much in his passing, but the high quality of his performances and character will be long appreciated.

W. V. BALDUF



Ulphian Carr Loftin, 1890-1946

Ulphian Carr Loftin, the son of Mr. and Mrs. James Oliver Loftin, was born on a farm near Mt. Olive, North Carolina, on July 2, 1890. His early life gave him a lasting sympathy for the country and for farming people.

Carr was the eldest of a family of nine children and is survived by all of them. On December 22, 1920, he married Aimee Marguerite LeBeuf of New Orleans. His wife survives him, as well as his son Lieutenant U. C. Loftin, Jr. of the United States Army Air Corps stationed in Honolulu, Hawaii, and his daughter Aimee M. Loftin.

Mr. Loftin went from a country school to the Mt. Olive High School where he graduated in 1906. That fall he enrolled in the University of North Carolina at Raleigh, graduating in June 1910 just before his 20th birthday. In the fall of 1910 he entered the University of Florida with a fellowship and received a Master's degree in 1913 from that University.

Following his school training he entered the service of the Bureau of Entomology of the U. S. Department of Agriculture for work under the supervision of the late Dr. W. D. Hunter. His first assignment was in connection with the investigations on sugar cane insects with headquarters at the Audubon Park Sugar Cane Experiment Station of Louisiana State University in New Orleans.

In 1914 the Bureau assigned Mr. Loftin to work on the pink bollworm of cotton. These investigations took him across the border into Mexico. In this work, he impressed both the technical workers and the practical cotton growers. In 1920 he accepted the position of Field Manager of Compania Tlhaulilo, a British-American agricultural organization operating in Mexico. The estate of this Company comprised 112,000 acres with about one-third of the area under irrigation for the cultivation of wheat and cotton. Wishing to return to research

work, in the fall of 1929 he accepted a position with the Sugar Cane Experiment Station of the Cuba Sugar Club to take charge of the entomological work in progress at Baragua, Cuba. This new field was under the supervision of the Tropical Plant Research Foundation and was supported by the sugar cane growers of Cuba through funds deposited with the National Research Council. The work on sugar cane in Cuba was devoted primarily to the control of the sugar cane mosaic disease which threatened the sugar industry in that Island. During the comparatively short time he was engaged on the problem, Mr. Loftin and his assistants made important contributions toward the solution of the problem.

In May 1931 Mr. Loftin returned to the service of the U. S. Department of Agriculture, Bureau of Entomology, accepting an assignment to undertake a survey of the pink bollworm situation in Puerto Rico and the Virgin Islands. His instructions included a consideration of the possibility of growing cotton in those areas to supplement their exports of sugar and rum. On account of the high infestations of the pink bollworm found in wild cotton, the report advised against the promotion of cotton production in these Islands.

On October 7, 1931 Mr. Loftin was called to Washington, D. C., his new assignment being Assistant Chief of the Division of Cotton Insect Investigations. His untimely death occurred suddenly on the night of January 16, 1946 following a full day's work at his office.

Carr Loftin gave his best to everything that he did. He accounted only to himself for his actions and he met the issues that confronted him on the basis of his own judgment. He was true to himself and it follows that he was true to his work, friends, and associates.

Through the death of Mr. Loftin the Association of Economic Entomologists has lost one of its faithful members. Aside from the loss to the Association the field of entomology has lost one of its outstanding authorities on cotton and sugar cane insects and the Bureau of Entomology and Plant Quarantine one of its most outstanding officials.

D. L. VAN DINE
A. S. HOYT

Fabian Garcia, 1871-1948

Fabian Garcia, son of Ricardo and Refugia Garcia, was born in Chihuahua, Mexico, January 20, 1871. His parents died when he was quite young and he was brought to New Mexico by his grandmother Doña Jacoba. They lived near Georgetown on the Mimbres River until 1885 and then moved to Las Cruces. Here he was graciously taken into the household of a prominent Mesilla Valley rancher, Thomas Casad, and the members assisted him in becoming acquainted with the manners and customs of his adopted homeland. He became a citizen of the United States in 1889. After completing somewhat interrupted periods of schooling at Georgetown and Mesilla, he entered the New Mexico College of Agriculture in 1890. Partially through the interest taken in his welfare by the College President, Hiram Hadley, and largely because of his own diligence he mastered the English language and completed the regular course of study in four years, receiving his baccalaureate degree with the first graduating class in 1894. While a college student he obtained his introduction to entomology from C. H. Tyler Townsend and T. D. A. Cockerell and his attention was early directed toward the need for investigating the habits of the codling moth, the wooly aphis, and the San José scale which were rapidly becoming important fruit pests in the orchards of the Territory of New Mexico. In 1895 he was appointed Meteorologist and Assistant in Horticulture for the Experiment Station, and from then on, until his retirement in 1945, his life was devoted to improving the agriculture of this state. In 1899 he became Assistant Professor; in 1901 Station Horticulturist and Head of the Department; and in 1913, Director of the Experiment Station. During the years 1899 and 1900 he pursued special courses in Horticulture under Liberty Hyde Bailey at Cornell University. He received the degree of M.S.A. from New Mexico State College in 1906 and was later awarded honorary Doctorates by both his Alma Mater and the University of New Mexico at Albuquerque. In 1907

DR. FABIAN GARCIA

he was married to Julieta J. Amador. One son was born, but died in infancy, and Mrs. Garcia died in 1920.

At various times during his life Dr. Garcia was an active member of numerous professional and civic organizations, principally the American Pomological Society, the American Historical Association, Alpha Zeta, Epsilon Sigma Phi, Knights of Columbus and Rotary International.

Dr. Garcia's first publication on insects, entitled *Spraying Orchards for Codling Moth* appeared in 1902. During the course of these investigations he discovered that spraying schedules developed in the East and Middle West, where the codling moth produces but two generations, did not give effective control in southern New Mexico. Consequently he initiated a program of life history study which led to the discovery that three and a partial fourth generation develop at State College and that "sideworm" injury was much more difficult to control than worm entry through the calyx. These studies were continued until 1908 during which time he developed a system of daily band records for determining the number of generations and the relation of spring emergence to the blooming periods of the several apple varieties grown commercially in southern New Mexico. As meteorologist he became interested in correlating the influence of spring weather factors on pupation and adult emergence and came to the conclusion that temporary depressions in temperature did not especially retard these phenomena.

Dr. Garcia's last comprehensive publication on insects was Bulletin 68, "Injurious Insects," which appeared in 1908. As indicated in the introduction, its purpose was "to disseminate information among gardeners, fruit growers, and farmers of the Territory in regard to those injurious insects which are now known to be more or less troublesome in this section and that are likely to become pests in the future." It records many personal observations concerning the distribution and comparative efficiency of control measures against such important insect pests as the harlequin cabbage bug, the squash bug, the wooly aphis, the clover mite, the migratory grasshopper and others. After the publication of this bulletin, Dr. Garcia turned his attention more and more to the problems of his own particular field, horticulture, but he never lost his active interest in insects and he continued to assist and direct the entomological projects of his associates. For a number of years he summarized and translated the results of these investigations into Spanish and had them published in the form of short, concise Press Bulletins in order to "make such information available to the Spanish speaking inhabitants of the Territory." This service, along with the fact that he utilized the opportunity afforded by the early Farmer's Institute and later by the Extension Service to visit practically every agricultural community in New Mexico and to discuss in both English and Spanish their agricultural problems, endeared him to farmers and ranchers throughout the Sunshine State. In 1930, at the request of the National Department of Agriculture of Mexico he conducted a lecture course on agricultural education and research in one of the Colleges of his native country across the border.

Among Dr. Garcia's most notable contributions to Horticulture are the yellow and white Grano varieties of onion and the College Chili Pepper No. 9. Under his own name he published 20 station bulletins and many more as co-author with his associates. The Fifty-sixth Annual Report of the Experiment Station was dedicated to him just after his retirement on April 1, 1945, and he was given the title "Director Emeritus of the Experiment Station and Professor Emeritus of Horticulture." Within the cover appears his picture and a biographical summary ending with the tribute "his is indeed a record of outstanding achievement and service to agriculture and to the people of New Mexico." He died in a local hospital after a long period of illness, August 6, 1948. When his will was made public, it revealed a bequest of $85,300 to his Alma Mater to be used in building a dormitory on the campus for poor youths with Spanish names, because as he said "I want to help poor boys for I know their hardships."

JOHN R. EYER

LIST OF RECORDED COTTON INSECTS OF THE WORLD. H. Hargreaves, F.R.C.S., D.I.C. (late Senior Entomologist, Uganda). 49 pages. Commonwealth Institute of Entomology. 41, Queens Gate, London, S.W. 7. Five Shillings. 1948.

This list of cotton insects names 1331 species, including 15 species of mites. The species are arranged by order and family and some attention is given to synonomy. The nature of the injury done by each species is suggested by a statement of the part of the plant on which it feeds. The countries from which each species has been reported are indicated. Eighty-two families representing eight orders are named. Of these, 185 species are listed as having been reported from the United States. A few of the records seem doubtful and the author has been careful to point out such cases.

Some interest attaches to the distribution of the species in the larger orders. In Coleoptera, 422 species are listed. Of these no less than 132 species are Curculionidae. The order Lepidoptera shows a total of 278 species of which 101 are Noctuidae. The order Hemiptera (including Homoptera) has a total of 421 species of which 160 are Homoptera. Pentatomidae total 70 species while Pyrrhocoridae has 55 species. Hymenoptera are represented by two bees (*Megachile*) and five species of ants. Only eight species of Diptera are indicated as cotton insects. Orthoptera number 118 species. The list contains 14 species of Isoptera and five of Collembola.

The indicated habitat of many of these species is such that they must be considered as potential invaders of our cotton fields. Our Foreign Plant Quarantine personnel could doubtless supply some interesting annotations to the list.

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